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DEPARTMENT OF THE ARMY TECHNICAL MANUAL **TM 5-243**

DEPARTMENT OF THE AIR FORCE MANUAL **AFM 95-6**

CARTOGRAPHIC AERIAL PHOTOGRAPHY

DEPARTMENTS OF THE ARMY AND THE AIR FORCE
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AIR FORCE MANUAL No. 95-6

HEADQUARTERS
DEPARTMENT OF THE ARMY
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CARTOGRAPHIC AERIAL PHOTOGRAPHY

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CHAPTER 1
INTRODUCTION

Section I. BACKGROUND

1-1. Purpose and Scope

a. This manual is intended for the training of personnel and for use as a reference by those whose duties include planning and evaluating cartographic aerial photography.

b. Specific information relating to the techniques of mapping with aerial photography is not included in this manual. Technical references providing this information are listed in appendix A.

c. Information contained in this manual is applicable without modification to both nuclear and non-nuclear warfare.

d. Users of this manual are encouraged to submit comments or recommendations for changes to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded directly to the Commandant, U.S. Army Engineer School, Fort Belvoir, Va. 22060.

1-2. History

The importance of aerial photography was first recognized during World War I when it became a military necessity. While Army commanders have always appreciated the need for good maps throughout the history of war, obtaining adequate topographic maps has sometimes been difficult. With aerial photography, apart from its immediate application to intelligence activities, a source for map information was found that could, in a comparatively short time, be used to produce new maps or revise outdated ones. When the United States became engaged in global operations during World War II, aerial photography achieved paramount importance with the rapid development of photogrammetry, for which aerial photography is the basic sourse of map data. It is in this field that photography becomes a science as well as an art. The aerial photograph is the result of the combined scientific and productive efforts of the optical designer, the camera manufacturer, the producer of photographic materials, the aircraft manufacturer, and the various people who use their products.

1-3. Uses of Aerial Photography

a. Aerial photography has wide application in mapping, ranging from the revision of detail on existing maps to the complete compilation of new maps by photogrammetric methods. Various types of photomaps are also produced from aerial photography, from uncontrolled expedients to highly accurate orthophotomosaics. Aeronautical charts, hydrographic charts, road maps, and other planimetric maps may be prepared in whole or in part from various kinds of aerial photography.

b. Aerial photography procured solely for the purpose of furnishing intelligence information does not fall within the scope of this manual. However, aerial photography flown for mapping purposes is also valuable in intelligence work. Photographic interpretation specialists at all levels are responsible for extracting information from aerial photographs which will contribute to the intelligence effort, and this includes the map compiler.

c. Cartographic aerial photography as discussed in this manual meets the specifications for the production of topographic maps by photogrammetric methods. A topographic map is one which presents both the horizontal and vertical detail in measurable form, so that distances, azimuths, and elevations may be accurately determined from the map by the map user.

d. There are two qualities which each aerial photograph must have if it is to be adequate for the preparation of topographic maps. First, the pictorial presentation of the terrain must be such that the topographic and planimetric detail can be identified and transferred to the map. Second, the geometric characteristics must be such that the relationship between the images can be measured and their positions established as they existed at the time of exposure.

1-4. Photogrammetric Instruments

a. Photogrammetric instruments in use by military topographic units are of two general types, the multiplex and the high precision military stereoplotter. These are both based on the photogrammetric principle of projecting the images of two overlapping photographs to create a three-dimensional spatial model which reproduces the relationship between the images which existed at the instant of exposure. After orienting the model to known control points plotted on a manuscript, the map compiler can measure and trace desired map detail from the model.

(1) The multiplex is more widely used by military photogrammetrists because it can be van-mounted and used in a photomapping train. It provides sufficient accuracy for most military requirements.

(2) The high precision military stereoplotter, because of its greater C-factor (para 3-2*c*), can be used to plot closer contour intervals or to compile at larger scales than the multiplex, and can utilize photography flown at a higher altitude. This instrument is used by topographic units which are not required to be mobile.

b. Since the accuracy of the maps stereocompiled with either of these instruments is dependent on the quality of the aerial photography, it is essential that personnel responsible for the planning and evaluation of cartographic aerial photography be experienced photogrammetrists. They must be completely familiar with both the capabilities and the limitations of the particular instrument to be used, before they can determine the photographic requirements of a project, or judge whether or not the photograph obtained is suitable.

Section II. TYPES OF MAPPING PHOTOGRAPHY

1-5. Types

Aerial photography may be classified according to the orientation of the camera axis (vertical or oblique), the lens system (single or multiple), or special properties (black and white, infra-red, color, radar). Cartographic aerial photography is taken with a precision type, calibrated mapping camera, and is most often classified according to orientation of the camera axis.

a. Vertical. A vertical photograph is taken with the axis of the camera lens as nearly vertical as possible. Vertical photographs are by far the most widely used for both mapping and intelligence, principally because the imagery is more easily converted to the orthographic projection of the map.

(1) Vertical photographs may be electronically controlled by the use of special techniques and auxiliary equipment, for example, HIRAN, SHIRAN, and TPR. HIRAN and SHIRAN are airborne electronic systems which employ electronic short range navigational principles to gather data for the extension or establishment of horizontal control. TPR (Terrain Profile Recorder) is the airborne electronic system used to obtain data to determine elevations of the terrain along the line of flight.

(2) Supplementary aerial photography (not necessarily cartographic) is used to augment the mapping photography and assist in the identification of features. Supplementary photography normally is of larger scale than the mapping photography and usually is procured simultaneously with the mapping photography.

b. Oblique. An oblique photograph is taken with the axis of the camera intentionally tilted from the vertical. A high oblique photograph is defined as one which includes a portion of the horizon while a low oblique does not. The principal advantage of oblique photography is the greater coverage compared to that of a vertical picture. This type of photography is seldom used today for topographic map compilation. Photography taken with the twin low oblique system referred to as *convergent* photography is obtained with two cameras mounted as closely together as possible with their respective axes tilted 20° in opposite directions from the vertical along the line of flight. (See fig. 1-1 for relationship of cameras.) The forward looking camera at one exposure station photographs the same area as the rearward looking camera at the next station (fig. 1-2). The shutters of these two cameras are synchronized to work simultaneously. The principal advantages of this type of photography are an increase in base-height ratio, which results in accentuated relief and increased stereoscopic acuity, and increased coverage. Stereoscopic models from convergent low oblique photographs cover about 2.2 times the area covered by models from vertical photographs taken from the same flight height. The disadvan-

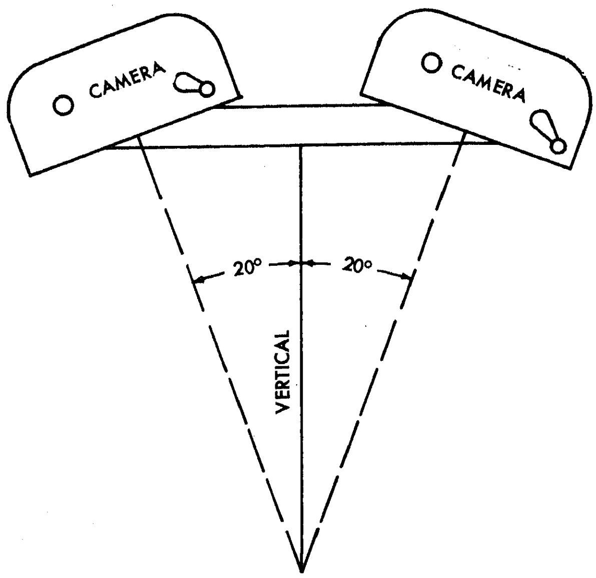


Figure 1-1. Relationship of cameras for convergent photography.

tages are the loss of resolution and imagery in the transformed prints used for reference and the relatively small scale in the portion of the photograph representing the area farthest from the camera. The two low oblique cameras can also be installed with the axes of the two lenses oriented in the aircraft perpendicular to the line of flight.

1-6. Criteria for Mapping Photography

Photography obtained for cartographic purposes is exposed by a calibrated airborne mapping camera. (Each camera has its own calibration certificate detailing the camera's optical characteristics (App. E)). This photography must conform to rigid cartographic requirements if an accurate map is to result. Outlined below are some basic mapping photography requirements.

a. It should clearly portray the terrain so topographic detail can be identified and transferred to the map.

b. The geometric characteristics of the photography must be such that the relationships between the images can be measured and their relative positions established.

c. The original negatives must be on dimensionally stable base film.

d. Acceptable processing techniques must be used.

e. The precision camera must have been recently service tested.

f. The aircraft must provide a stable platform for the camera.

g. Image motion must be within acceptable limits.

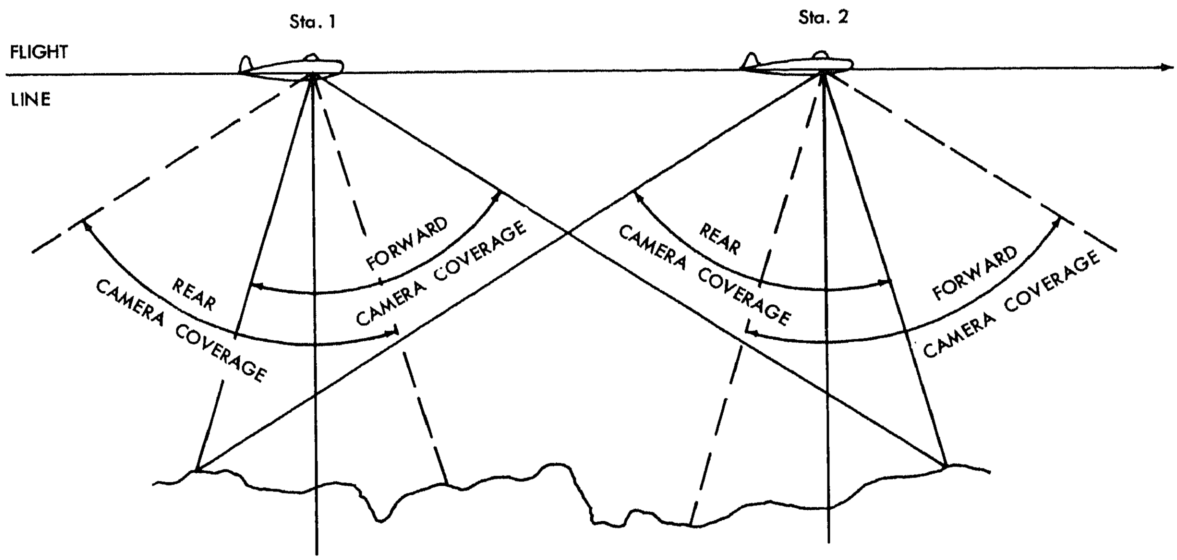


Figure 1-2. Convergent "Low Oblique" coverage.

Section III. CHARACTERISTICS OF VERTICAL AERIAL PHOTOGRAPHY

1-7. General

a. The characteristics of aerial photographs must be understood if they are to be used properly. It is essential to recognize the basic differences between an aerial photograph and a standard military map. These differences include the following:

(1) The photograph is a perspective projection of the terrain on a two-dimensional plane, while the standard military map is an orthomorphic (conformal) projection, that is, the scale at any point is the same in all directions, achieved by preserving right-angle intersections of meridians with parallels.

(2) The scale throughout the photograph is not constant; scale variations on the military map are negligible.

(3) The photograph is not always absolutely parallel to the corresponding ground plane.

(4) The camera lens is not entirely distortion free.

b. These characteristics generally cause some image displacement in the photograph. For practical purposes, however, a photograph may approach the accuracy of a map if the terrain included in the entire area of the photograph is flat, if the photograph is not tilted, and if the camera lens is distortion free. Since these conditions rarely exist together it is necessary to rectify the displaced features, as seen on an aerial photograph.

1-8. Photo Scale

The scale of the original negative is the ratio of a distance on the photograph to the corresponding distance on the ground. This ratio will depend on the focal length of the camera and the height of the camera above terrain at the movement of exposure. The variation of scale from point to point on a photo is due to image displacement caused by tilt of the camera and ground relief.

a. The scale of a photograph may be determined by comparing a distance between two images on the photo with the corresponding distance on the ground. These distances may be referred to as scale check lines. This method is based on the relation:

$$\frac{1}{D}=\frac{ab}{AB}$$

where D is the denominator of the scale fraction $\left(\frac{1}{D}\right)$, ab is a distance on the photo and AB is the corresponding distance on the ground.

Example: Given: distance on photo = 3 inches
distance on ground = 2 miles
Find: scale of photo

$$\frac{1}{D}=\frac{ab}{AB}$$

$$\frac{1}{D}=\frac{3}{2\times5280\times12}$$

$$\frac{1}{D}=\frac{1}{42{,}240}=\text{Scale of photo}$$

b. A second method for determining the mean scale of a photograph is by the relationship of the camera focal length to the altitude over mean terrain. The following equation expresses this relationship:

$$\frac{1}{D}=\frac{f}{H-h}$$

where D is the denominator of the representative fraction, f is the focal length of the camera, H is the flying height above sea level and h is the average or mean elevation of the terrain above sea level. See figure 1-3 for an example.

Example: Given: Camera focal length (f) = 6″
Flying height ASL(H) = 17,000′
Mean Terrain (h) = 5000′

$$\frac{1}{D}=\frac{f}{H-h}$$

$$\frac{1}{D}=\frac{.5}{17{,}000-5000}$$

$$\frac{1}{D}=\frac{1}{24{,}000}=\text{Scale of photo}$$

c. To determine the scale of a photo by comparison with a map, the following equation may be used.

$$\text{photo scale}=\frac{\text{distance on photo}}{\text{corresponding distance on map}}\times\text{map scale}$$

Example: Given: Map distance = 3″
Photo distance = 6″
Map scale = 1:50,000
Photo scale = $\frac{1}{D}$
Find: The scale of the photo.

$$\frac{1}{D}=\frac{6}{3}\times\frac{1}{50{,}000}$$

$$\frac{1}{D}=\frac{1}{25{,}000}=\text{Scale of photograph}$$

In order to offset the effects of tilt two scale check lines (the measured distance between two images on the photo) should be obtained instead of one. It is preferable that these lines be relatively long, interesect at approximately right angles, and be

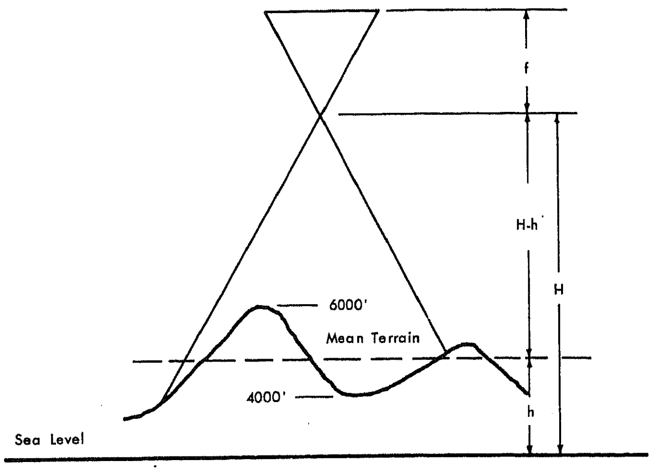


Figure 1-3. Scale determination.

centrally located on the photograph. It has been pointed out that the scale of a photograph is directly proportional to the flying height and the focal length of the camera. A vertical photo exposed 10,000 feet above the ground will be of a larger scale than a photograph exposed with the same camera at 15,000 feet above the ground. Therefore, it is concluded that the nearer an object is to the camera the larger the scale of the image of the object on the photograph. For this reason the top of a mountain will be at a larger scale than a valley on the same photograph.

1-9. Image Displacement Caused by Relief

a. Basic Principles. In considering relief displacment, let us assume the photograph to be truly vertical. Also, for ease of presentation the points as represented in figure 1-4 are shown on the ground, the datum plane, and on the negative plane of the photograph. Figure 1-4 shows a typical section of terrain photographed through L, the camera lens. Points D, P, and C are points on the ground. Since point P is the intersection of the ground and plumb line, it is called the "plumb point" or "ground nadir". The datum plane of a photograph is positioned at the point where the plumb line strikes the ground, as illustrated by figure 1-4. All points on the ground *above the datum plane* are displaced on the photograph away from the nadir and all points on the ground *below the datum plane* are displaced toward the nadir. On a truly vertical photo the nadir point and the principal

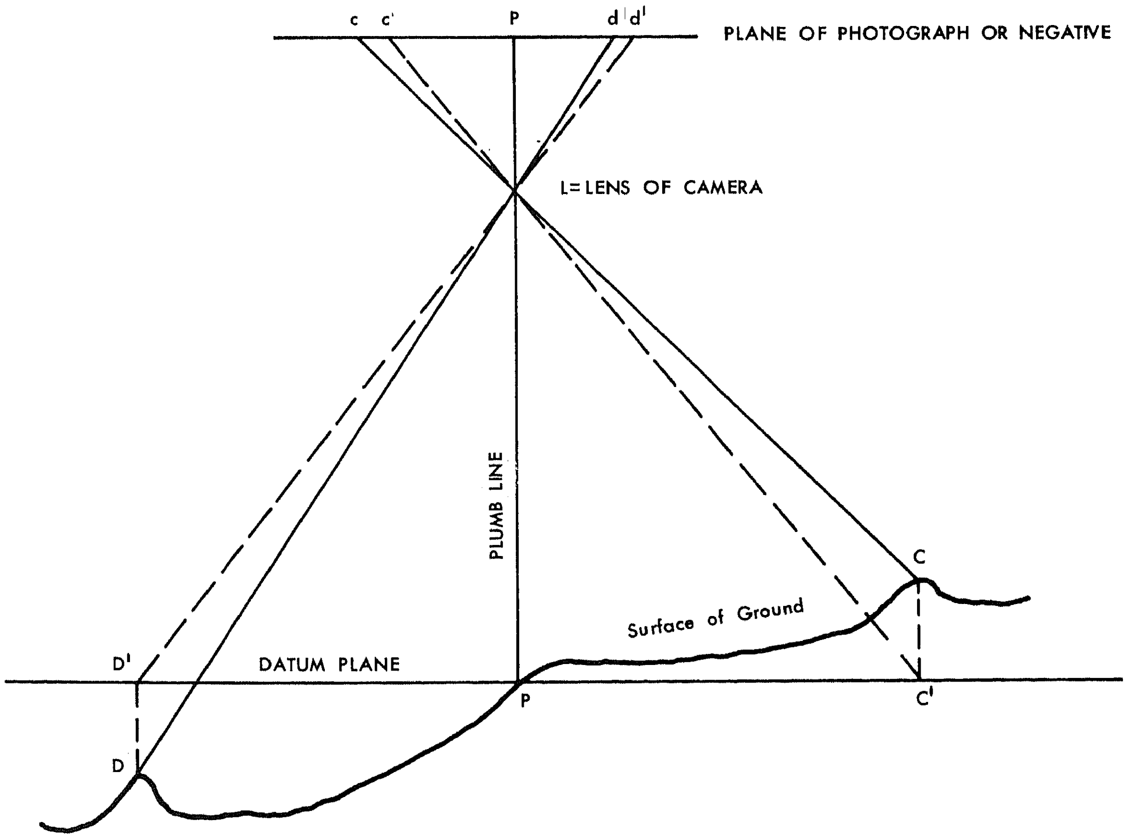


Figure 1-4. Displacement of images caused by relief.

point are coincident. The principal point is the intersection of lines from opposite fiducial marks, which are index marks centered on each side of the photograph. In practice where tilt does not exceed more than 2°, the principal point may be used as the nadir point. In radial triangulation the positions of the various corresponding images on the radial lines are determined by intersection from two or more nadir points of adjacent photographs. TM 5-240 describes this method of establishing horizontal photogrammetric control.

d. Determining Heights From a Single Vertical Photograph. Heights of objects on a single photograph may be determined by making measurements directly on the photograph. The measurements are made along the radial from the nadir point to the top and bottom of the image. Figure 1-5 illustrates how parallactic displacement is applied to determine heights of objects on single vertical photographs. Photographs used for such measurements should not be tilted more than 2° from the vertical and their scale should be accurately determined by the methods described in paragraphs 1-8 *a* or *c*.

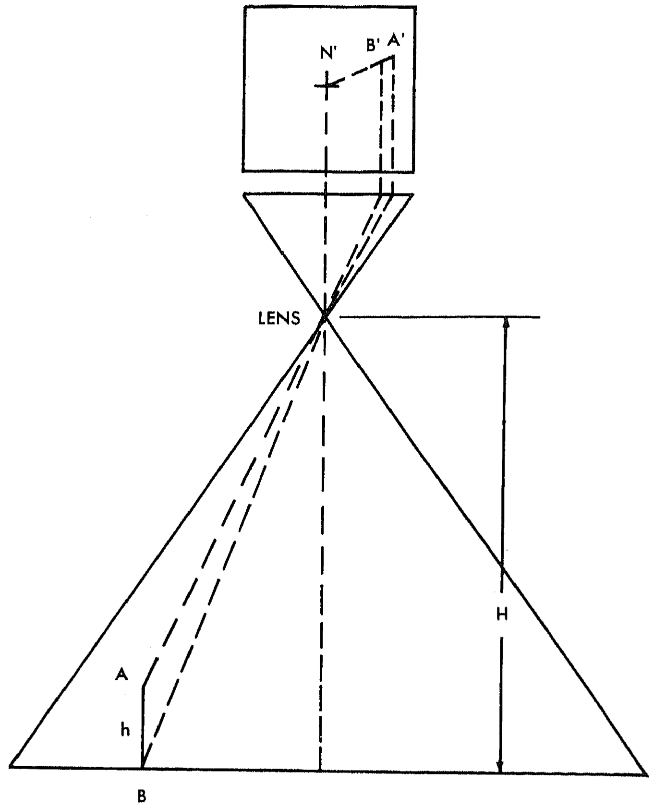


Figure 1-5. Height determination.

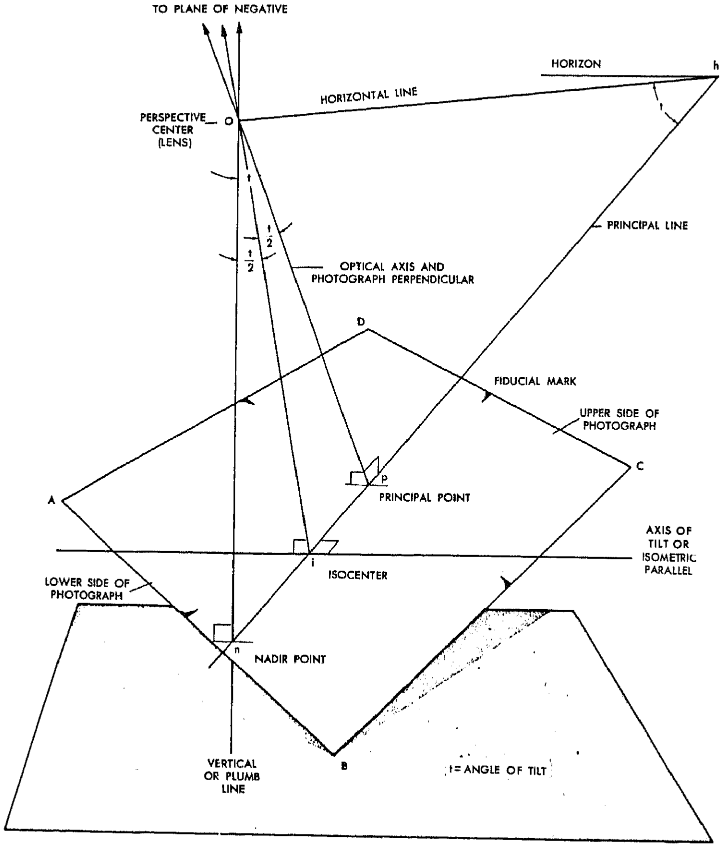


Figure 1-6. Nomenclature related to a tilted photograph.

$$h = \frac{(A'B')H}{A'N'}$$

Example: Given: A′N′ is 6 inches (distance from nadir to top of image)
A′B′ is 0.075 inch (displacement of image)
H is 20,000 feet (altitude of aircraft)

$$h = \frac{(0.075)\ 20{,}000}{6} = 250 \text{ feet (height above ground)}$$

1-10. Image Displacement Caused by Tilt

a. The vertical aerial photograph at the time of exposure is seldom parallel to the ground it represents. Under good operation conditions the camera may be accidentally tilted a small amount, usually less than 3°. High winds, turbulent air, uncontrollable changes in altitude and the high speed of the aircraft make it nearly impossible to maintain the camera perfectly level throughout the flight.

b. On a truly vertical photograph the optical axis and the plumb line are coincident. When the camera is tilted the optical axis is tilted away from the plumb line. The angle formed by these axes is called the angle of tilt. The point on the photograph pierced by the bisector of the angle of tilt is called the isocenter. The line through the nadir, isocenter, and principal point is referred to as the principal line. This line (and all lines parallel to it) is the line of maximum inclination. The tilt axis or isometric parallel is perpendicular to the principal line through the isocenter. Figure 1-6 illustrates these relationships.

c. A tilted camera, at the instant of exposure, photographs a trapezoidal ground area. The raised portion of this tilted photograph contains the photographic record of a larger ground area than the lower portion; therefore, the resultant photograph is not of equal scale throughout. The portion of the print (the raised portion) which contains the image of the larger ground area is of smaller scale than the lower portion. Figure 1-7 illustrates a tilted mapping camera and photograph. Images displaced on the photograph because of tilt are radial from and toward the isocenter. Those on the upper side of the photograph are displaced toward the isocenter and images that appear on the lower side radiate away from the isocenter. There is no image displacement caused by tilt along the isometric parallel (axis of tilt) relative to an equivalent untilted photograph.

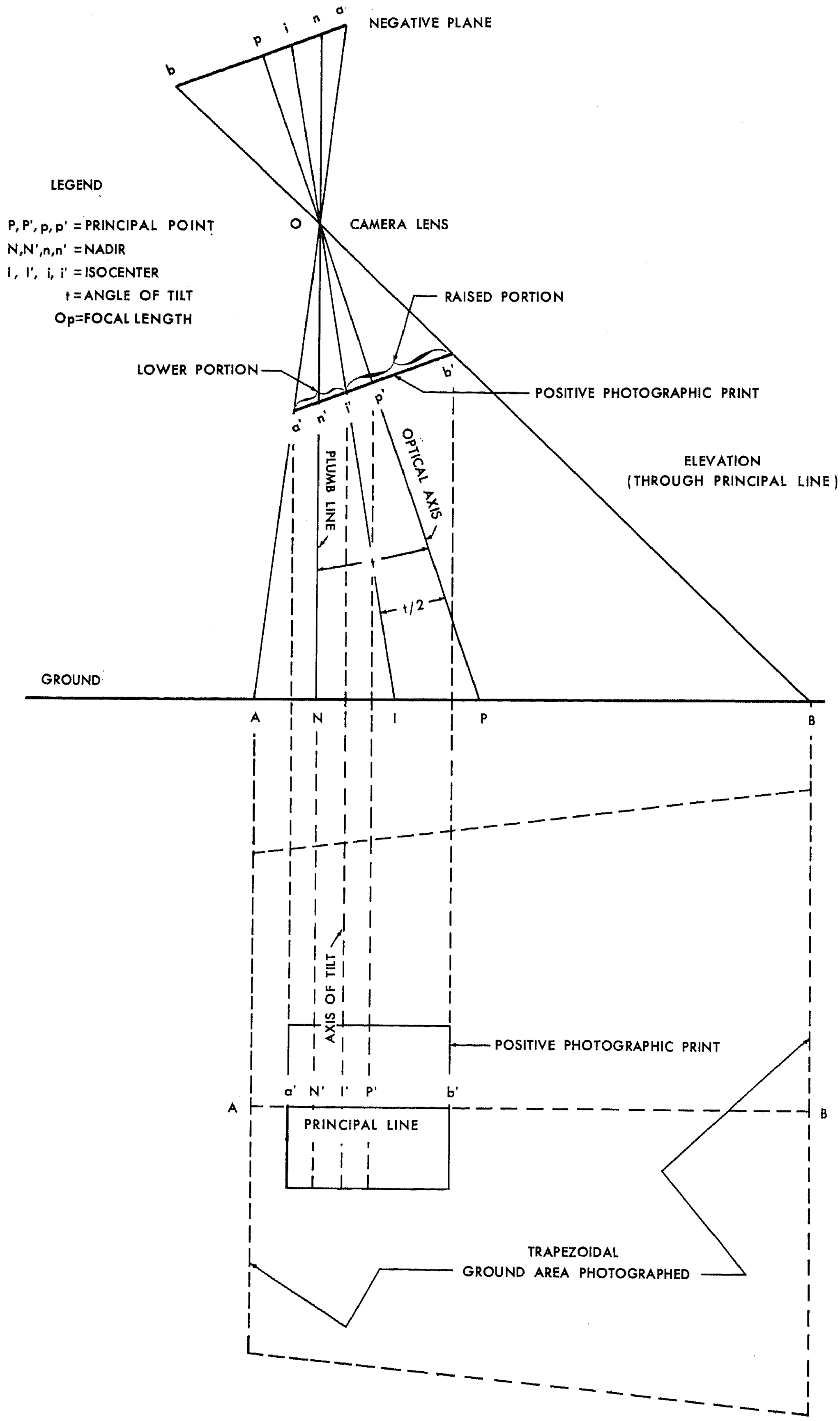


Figure 1-7. Effect of camera tilt.

CHAPTER 2
AERIAL CAMERAS

2-1. General

There are many types of aerial cameras, each of which is designed for a particular purpose. This manual is concerned with those used for mapping. A widely used cartographic aerial camera is shown in figure 2-1. The design and contruction of a camera determines to a large extent the suitability and quality of the aerial photographs. In particular, phtoographs that are to be used in stereoplotting equipment must be exposed in cameras manufactured and calibrated to a degree of precision equal to or, if possible, exceeding the precision of the stereoplotting equipment to be used. In view of the importance of the aerial camera in the production of suitable photography for mapping purposes, an understanding of the basic parts of camera construction is essential. Any defects in the aerial photography caused by malfunction of the camera must be recognized in order to evaluate the photography properly.

2-2. Aerial Camera Components

a. Regardless of the purpose for which each camera is intended, all consist of the same basic components: a light-tight box, a lens, a shutter, and an image plane. A schematic diagram showing the relationship of the essential parts of the cartographic camera is shown in figure 2-2, and is described below.

(1) *Lens.* The lens is a very important element of a camera. In fact, aerial photography is often classified according to the lens system used in the camera. The type of lens usually specified for present day mapping is either the wide-angle or the super-wide angle, also called the ultra-wide angle, lens. The angular coverage for a lens is referred across the diagonal of the negative. The *effective* angular coverage is frequently less than the cited angular coverage because a portion of the corners of the format may not be usable owing to distortion, the resolving power of the lens, and the general photographic quality. The effective angular coverage of the wide-angle lens, 6-inch focal length mapping cameras is about 90°, while that of the super-wide angle lens, 3½-inch focal length, mapping camera, is about 120°, both with the 9″ x 9″ format. It should be noted that the focal length used to identify a particular type of lens system is *nominal* only. The actual focal length is listed in the calibration certificate for each camera, and is the measurement which is used for any precise mathematical computations involving the camera focal length. The camera lens must meet strict specifications. It must be nearly free of distortion, or have a type of distortion that can be compensated for or removed during the mapping process. It must have resolving power, that is, it must define images to a specified degree of clarity. The function of the lens is to collect a selected bundle of light rays for all points on the terrain and to bring each bundle into focus as a point on the focal plane. The aerial camera has a fixed focus set for an object distance of infinity.

(2) *Lens cone.* The lens is supported at a fixed distance from the film by the lens cone. The lens cone also prevents any light except that transmitted through the lens from striking the film. In mapping cameras the lens cone insures the positioning of the lens in relation to the fiducial marks. The fiducial marks are index marks, most often located in the center of each of the four sides of the negative opening of the focal plane in such a position that their images are recorded on the negative. They are included in all aerial cameras used for mapping and serve (by the intersection of lines joining opposite marks) to locate the principal point on the negative.

(3) *Shutter and diaphragm.* The shutter and diaphram assembly functions as a light valve, permitting light to pass through the lens to the sensitized film. The shutter controls the length of time light is permitted to pass through the lens and the diaphragm (f/stop) governs the amount of light permitted to strike the film.

(4) *Camera body.* The camera body houses the drive mechanism which actuates the shutter, diaphragm, and transports the film. The lens cone is attached to the bottom of the camera body. The upper surface of the camera body provides a seating surface for the film magazine.

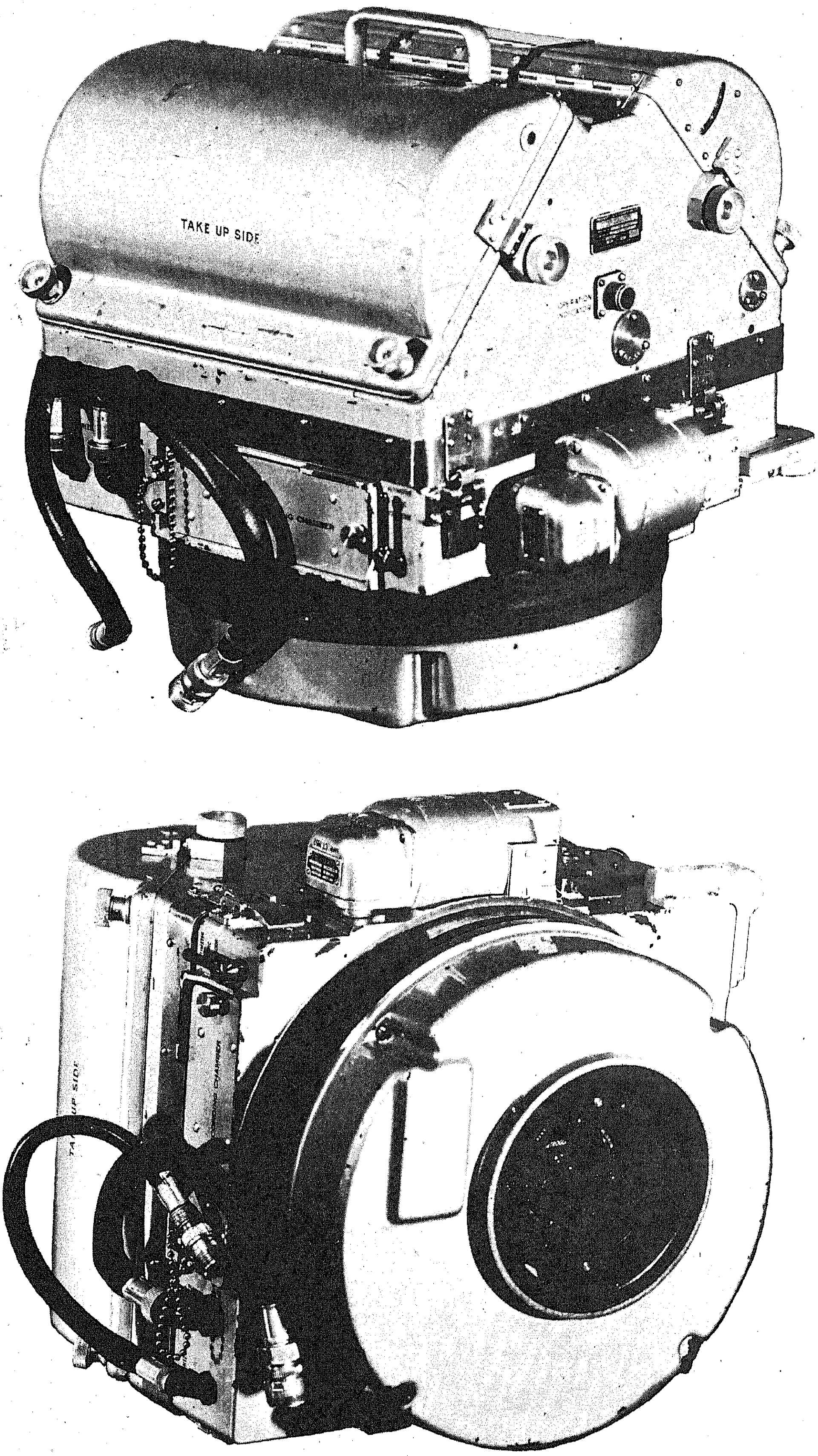


Figure 2-1. Typical aerial camera.

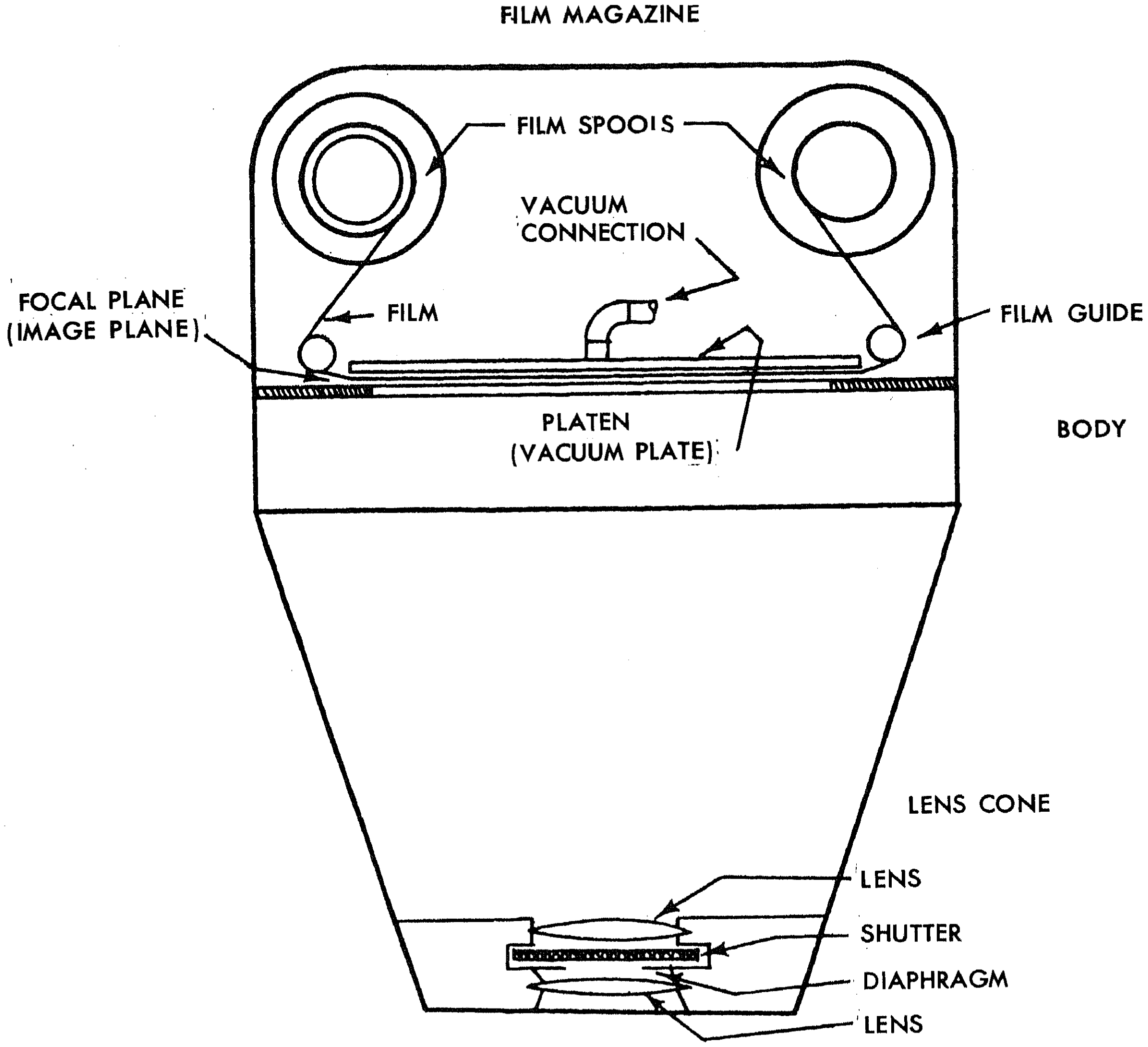


Figure 2-2. Schematic diagram of an aerial camera.

(5) *Film magazine.* The film magazine is essentially a container for film. It also winds the film after exposure, using power from the camera drive mechanism. It contains the platen to hold the film flat in the focal plane at the moment of exposure, thus preventing distortion in the image perspective registered on the film. Film flattening usually is accomplished by the vacuum system. At the instant of exposure, this system evacuates the air from the space between the film and the platen insuring that the film surface is flat and lies in the focal plane.

(6) *Intervalometer.* The intervalometer is a timing device which controls the amount of forward overlap, automatically operating the shutter of a camera at a predetermined time interval. Terrain conditions sometimes necessitate manual operation or adjustments in order to maintain the desired for forward overlap.

b. Camera mounts. The camera mount must absorb vibrations set up by the aircraft and keep the camera oriented in the required position. The various types are the fixed, the adjustable, and the gyrostabilized mounts.

(1) *Fixed mount.* In the fixed type of mounting the aerial cameras are secured rigidly to the frame of the aircraft in such a position that they point out through the openings provided. They may be mounted to point vertically downward or to either side, forward to aft at the desired angle from the vertical. Several cameras may be mounted in this manner and may be used with or without other cameras set in another type of mounting. The usual type of fixed mount places the camera in a position to cover an area vertically below the aircraft.

(2) *Adjustable mounts.* Adjustable mounting is more desirable than fixed mounting. By this

method the camera is suspended in a mount which may be rotated about three mutually perpendicular axes. The camera is manually oriented so that the optical axes is vertical at the instant of exposure, and it may be rotated so that the sides of the photographic frame are parallel to the direction of travel of the aircraft over the ground. Tilt usually is determined by reference to a level bubble mounted on the camera or the control mechanism. A viewfinder or drift sight is used to determine the angle between the axis of the aircraft and its path over the ground.

(3) *Gyrostabilized mounts.* The gyrostabilized mount uses a gyroscopic stabilizer to maintain the position of the vertical camera in the aircraft. The method of suspension is essentially the same as in the adjustable mount. The gyroscope returns the camera to its original vertical position from any deviation caused by the motion of the aircraft. Gyro stabilized vertical camera mounts in use by the Air Force are the A–28, the ART 23, and the ART 25. These mounts correct any deviation up to 8° from the vertical and return the camera to its original position at a normal rate of 2° per minute. Recent developments include the LC–7A and LC–8A gyrostabilized mounts used with the AN/USQ–28 Aerial Geodetic Photomapping System.

2–3. Classification of Cameras

Aerial cameras may be classified in many ways. For the purpose of this manual mapping cameras are grouped according to the angular coverage and focal length of the lens. The two most commonly used types are the wide-angle, 90°, 152-mm focal length, and the super-wide angle 120°, 88-mm focal length, both with the 9″ x 9″ format (para 2–2*a*(1)). It is apparent that the wider the angle of coverage the shorter the focal length. A comparison of angular coverage between types of lenses is shown in figure 2–3.

a. Wide Angle (90°). The most extensively used mapping camera is the USAF KC–1B which has a wide-angle Planigon lens. A camera presently under development, the KC–6A, is equipped with a GEOCON IV lens which has a higher resolving power than the Planigon lens of the KC–1B. Its shutter speed has been increasd to compensate for today's developments in aerial film and greater aircraft speeds. The effective angular coverage of the lens has been increased by 2° over that of the Planigon lens.

b. Super-Wide (or Ultra-Wide) Angle (120°). The 88-mm focal length super-wide angle mapping camera is practical in military mapping operations for mapping at smaller scales and greater contour intervals than the wide-angle mapping camera. This type of photography may be exposed at a lower altitude (three-fifths of the altitude required for a 6″ FL camera) and still attain a photo scale the 6″ FL camera would produce at the higher altitude. The advantages in using this camera are two fold: the lower altitude makes it possible to fly under cloud cover in consistently cloudy areas, such as the tropics; and planes that cannot reach the higher altitudes may be used for photo missions. This type of photography should not be planned unless the companion mapping equipment is available. Preparation of photomaps is not recommended with this type of photography because of its greater image displacement.

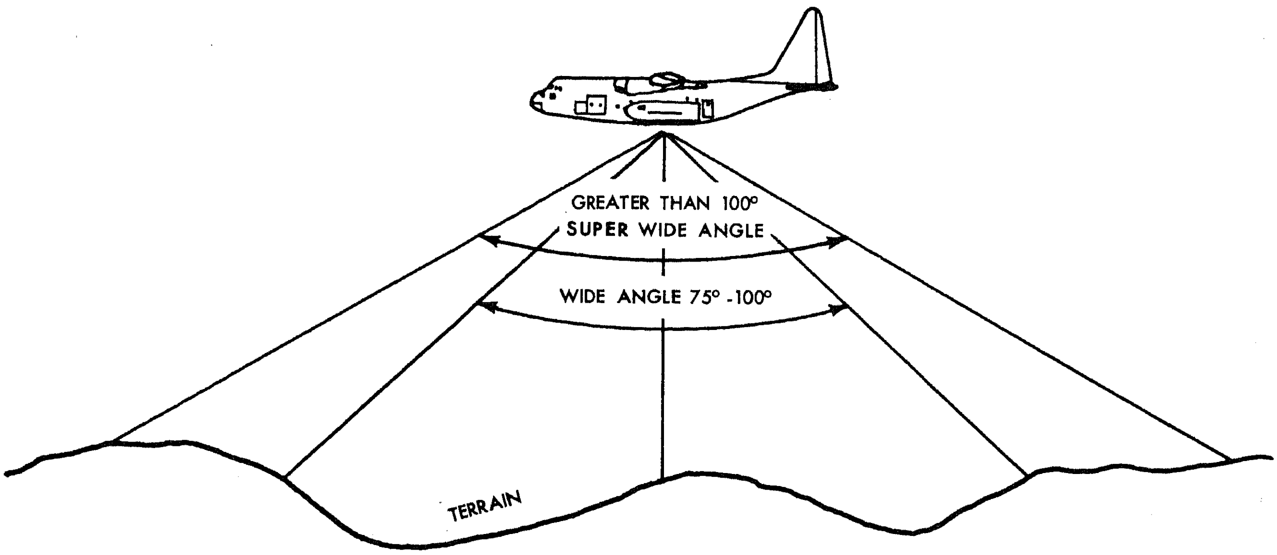


Figure 2–3. Angular coverage comparison.

CHAPTER 3
PLANNING AERIAL PHOTOGRAPHY

Section I. FLIGHT PLANNING

3-1. Introduction

a. The Defense Intelligence Agency (DIA) is responsible for the management of cartographic aerial photography resources for the Department of Defense. In this capacity, DIA validates requests for mapping photography from DOD elements, and assigns the project to an appropriate military organization for accomplishment. Coordination channels with other arms and services for mapping photography in a theater of operations are discussed in FM 5-146.

b. Careful planning is necessary for the procurement of cartographic aerial photography. The requesting organization establishes the basic requirements for the mapping project, which include the geographic location, the extent of the area to be mapped, the type, scale and accuracy of the proposed maps, the contour interval, and the completion date. The flight planners, upon receipt of these requirements, collect source materials such as photo indexes of existing photography, maps and available geodetic control, and obtain geographic and weather information relating to the area. These materials are studied in conjunction with the mapping requirements to determine the most feasible and economical flight plan. The results of these studies are documented in the Specific Project Data (SPD), which is described in detail in section II of this chapter.

3-2. Influencing Factors

The many factors that influence the flight plan must be considered during the study and evaluation of the available source.

a. Direction of Flights.

(1) Flight direction may be influenced by the distribution and density of the existing control. Ground control must be "photo-identifiable" to be usable by the map compiler. Insufficient photo-identifiable control may necessitate the acquisition of additional control though ground surveys, if the area is accessible. If the existing control is inadequate for the mapping of an area, a control plan is initiated for the establishment of picture point control on completion of the photographic mission. Ground control to be used in photogrammetric projects must be in bands at predetermined distances and must cross at approximately right angles to the flight lines. Cross flights provide a means of establishing photogrammetric control when placed to take advantage of ground control. Bands of cross flights suitably placed satisfy the control requirements for the project. The size and location of the area may also affect the type of control to be used. Consideration must be given to the use of electronically controlled photography, if the size and location of the area prohibit conventional methods of acquiring control. Large inaccessible areas can be mapped economically and in less time with electronically controlled photography (*d* below).

(2) The shape of the area to be photographed also influences the direction of flights. Normally the flights are planned to be parallel to the long dimension of the area. If the limits of the area to be photographed are bounded by meridians and parallels the flight lines normally run north-south or east-west. The direction of flight which most nearly meets the requirements and covers the area with the least number of flights is chosen.

(3) The relief of the terrain in the project area may influence the flight direction, and the amount of forward overlap and sidelap. Since mountain ridges and other high features cause a scale change in the photography (as explained in chap 1, sec III), caution must be exercised in spacing the flight lines to avoid possible gaps. It is advisable to position the flights parallel to the mountain ridges, thereby avoiding possible stereo gaps in the resultant photography.

b. Time of Year.

(1) Weather is an important factor in most parts of the world in the procurement of aerial photography. Certain tropical countries almost always have cloud cover, haze, or dust. The atmosphere on an ideal photographic day should be free

of clouds, dust, smoke, and haze, and with a minimum of air turbulence at the flight altitude. Also, the altitude of the sun should be high enough during the photographic mission to avoid objectionable long shadows. Weather conditions peculiar to the area may shorten the photographic season. Therefore, the size of the area and weather conditions may warrant dividing the project area into several smaller areas to be completed over several photographic seasons. Another solution is to employ additional aircraft and personnel to complete the photographic project in one or two seasons.

(2) Ground cover conditions should be carefully considered in determining the time the photography is flown. Undesirable snow, foliage, floodwaters, or other cover that obscures ground features should be avoided whenever possible. It is very difficult, and sometimes impossible, to plot contours, trace map detail, or identify control using summer photography of forested areas, or winter photography of ground covered with deep snow. For this reason, mapping photography of wooded terrain in the temperate zone is flown whenever possible in the spring after the snow has melted and just before the leaves appear. A light fall of snow on timbered areas is not objectionable however, and can, in some cases, aid in the delineation of detail.

c. Altitude. The type and scale of the map to be prepared determine to a large extent the camera and photogrammetric equipment to be used. In turn, the plotting of accuracy of the photogrammetric equipment and the specified contour interval dictate the altitude of the aircraft.

(1) The best flight altitude above mean terrain (AMT) for photography for a specified contour interval may be determined by multiplying the contour interval by the C-factor of the plotting instrument to be used. The C-factor is expressed as follows:

$$\text{C-factor} = \frac{\text{Flight altitude (AMT)}}{\text{Least contour interval accurately plottable}}$$

This factor is an empirical constant which is derived from the optical, photographic, and other qualities of the plotting system. The C-factor may range from 600 to 800 for the multiplex and 850 to 1200 for the high precision stereoplotter.

(*a*) To determine the flight altitude (AMT), with the given contour interval of 20 feet and the multiplex C-factor at 600:

$$\text{Flight altitude} = 20 \text{ feet} \times 600$$
$$\text{Flight altitude} = 12{,}000 \text{ feet}$$

It is therefore apparent that a 20-foot contour interval can usually be plotted with the required accuracy at a scale of 1:10,000 (multiplex plotting scale being 2.4 times the photo scale of 1:24,000).

(*b*) The C-factor for the high precision stereoplotter is generally 1000. To determine the flight altitude (AMT) with the given contour interval of 20 feet:

$$\text{Flight altitude} = 20 \text{ feet} \times 1000$$
$$\text{Flight altitude} - 20{,}000 \text{ feet}$$

(2) At a flight altitude of 20,000 feet, contours at 20 foot intervals can be plotted within the required accuracy. Since the high precision stereo plotter enlarges the photo scale 5 times, the plotting scale (viewing scale) will be 1:8,000. By using this plotter, instead of the multiplex, we find that the flight altitude can be substantially higher, resulting in smaller scale photography, without sacrificing the desired contour interval of 20 feet. Photography flown at 20,000 feet has a scale of 1:40,000, thus requiring fewer photographs to cover the area. Table 3-1 shows the relationship of the flight altitude, photo scale, and plotting or viewing scale for the two different stereoplotters. The above are examples and not intended to cover all of the many refinements of photogrammetric plotting equipment.

d. Electronically Controlled Photography.

(1) If there is a lack of ground control, or if the cost and time available do not permit the establishment of ground control in an area, the use of electronically controlled photography may be warranted. The size and location of the area may also have a bearing on whether electronically controlled photography is to be used. This type of photography has certain limitations, and therefore must meet established standards to fulfill the accuracy requirements for class A mapping. Procedures for obtaining acceptable photography controlled by HIRAN, SHIRAN, or terrain profile recorder (TPR) methods are described in DIAM 70-6-1.

(2) For mapping projects at 1:50,000 or 100,000 scale, flight lines of electronically controlled photography must be at least seven exposures in length. All exposures of a seven-exposure flight line must be controlled. No more than 20 percent of a flight line longer than ten exposures may be uncontrolled, and no more than four consecutive exposures may be uncontrolled.

(3) For 1:250,000 scale mapping, a grid of HIRAN cross flights transverse to the basic mapping photography is adequate in most cases. For this type of coverage, each flight line shall cross at least three transverse electronically controlled

flight lines of the grid pattern. The number of uncontrolled exposures shall not exceed 20 percent, nor shall the number of consecutive uncontrolled exposures exceed four.

(4) The first two and last two exposures of all flight lines shall be electronically controlled.

(5) Vertical control established with the airborne terrain profile recorder (TPR), which in turn is indexed on reference points of known elevation, usually is not adequate for large scale mapping (20-meter contour interval or less). Selected vertical picturepoint control is required and these points must be photo-identified in the field. However, in medium-scale mapping (100 meter contour interval or less), HIRAN cross flights combined with the TPR cross flights are adequate in most cases for the establishment of vertical control.

Table 3-1. Flight Planning Data for 6" Focal Length Camera With 9" x 9" Format

Flight altitude in feet (above mean terrain)	Scale of photography	Net forward gain per model		Photo width in miles	Photo area in sq miles	Area of net model 20% side lap		Area of net model 30% side lap		Flight line spacing for side lap of:		High precision military plotter*		Multiplex	
		Forward lap				Forward lap		Forward lap		20%	30%	Viewing scale	Contour interval (feet)	Viewing scale	Contour interval (feet)
		56%	60%			56%	60%	56%	60%				ALT / 1000		ALT / 600
6,000	1:12,000	0.75	0.68	1.70	2.89	1.02	0.93	0.90	0.81	1.36	1.19	1:2,400	6.0	1:5,000	10.0
8,000	1:16,000	1.00	0.91	2.27	5.15	1.81	1.65	1.59	1.45	1.82	1.59	1:3,200	8.0	1:7,000	13.3
10,000	1:20,000	1.25	1.14	2.84	8.07	2.84	2.58	2.48	2.26	2.27	1.99	1:4,000	10.0	1:8,000	16.7
12,000	1:24,000	1.50	1.36	3.41	11.63	4.09	3.72	3.58	3.25	2.73	2.39	1:4,800	12.0	1:10,000	20.0
14,000	1:28,000	1.75	1.59	3.98	15.84	5.58	5.07	4.74	4.31	3.18	2.78	1:5,600	14.0	1:12,000	23.3
16,000	1:32,000	2.00	1.82	4.54	20.61	7.25	6.59	6.23	5.67	3.63	3.18	1:6,400	16.0	1:13,000	26.7
18,000	1:36,000	2.25	2.04	5.11	26.11	9.19	8.35	7.98	7.26	4.09	3.58	1:7,200	18.0	1:15,000	30.0
20,000	1:40,000	2.50	2.27	5.68	32.26	11.36	10.32	9.98	9.07	4.54	3.98	1:8,000	20.0	1:17,000	33.3
22,000	1:44,000	2.75	2.50	6.25	39.06	13.75	12.50	12.10	11.00	5.00	4.37	1:8,800	22.0	1:18,000	36.7
24,000	1:48,000	3.00	2.73	6.82	46.51	16.37	14.88	14.32	13.02	5.46	4.77	1:9,600	24.0	1:20,000	40.0
26,000	1:52,000	3.25	2.95	7.38	54.46	19.17	17.43	16.86	15.33	5.90	5.17	1:10,400	26.0	1:22,000	43.3
28,000	1:56,000	3.50	3.18	7.95	63.20	22.25	20.22	19.66	17.87	6.36	5.57	1:11,200	28.0	1:23,000	46.7
30,000	1:60,000	3.75	3.41	8.52	72.59	25.55	23.23	22.45	20.41	6.82	5.96	1:12,000	30.0	1:25,000	50.0
32,000	1:64,000	4.00	3.64	9.09	82.63	29.09	26.44	25.65	23.32	7.27	6.36	1:12,800	32.0	1:27,000	53.3
34,000	1:68,000	4.25	3.86	9.66	93.32	32.85	29.86	28.84	26.22	7.73	6.76	1:13,600	34.0	1:28,000	56.7
36,000	1:72,000	4.50	4.09	10.22	104.45	36.77	33.42	32.18	29.26	8.18	7.16	1:14,400	36.0	1:30,000	60.0
38,000	1:76,000	4.75	4.32	10.79	116.42	40.98	37.25	35.98	32.70	8.63	7.55	1:15,200	38.0	1:32,000	63.3
40,000	1:80,000	5.00	4.54	11.36	129.05	45.43	41.30	39.67	36.06	9.09	7.95	1:16,000	40.0	1:33,000	66.7

*Pantograph reduction capacity ½—⅕ of viewing scale.

Section II. SPECIFIC REQUIREMENTS

3-3. Technical Provisions

a. General instructions for the procurement of photographs are included in DIAM 70-6-1. Specific instructions relating to a particular project are contained in the specific project data (SPD) for that project, which is prepared by the requesting organization. A sample SPD may be found in appendix B. The provisions of the SPD furnish certain information and define in precise terms the conditions which must be satisfied in order to complete the photographic mission successfully. These include the following:

(1) Project name or code name, if classified.

(2) Photography to be obtained.

(3) Cross flights, grid flights, special flights.

(4) Flight altitude above sea level.

(5) Solar altitude.

(6) Sidelap, forward overlap.

(7) Camera(s) to be used.

(8) Diagrams showing area to be photographed.

(9) Camera service test.

(10) Materials to be delivered (to the requesting organization).

(11) Charts to be furnished by the requesting organization.

b. These technical provisions, which are tailored to the specific requirements for the project, are explained below.

(1) The designated name or code name is self-explanatory.

(2) The item "Photography to be obtained" specifies the size of the area or areas to be photographed, type of photography and whether it is to be electronically controlled, supplementary photography if required, direction of flights, and priority.

(3) Cross flights are used to minimize ground control requirements or for bridging existing ground control by photogrammetric techniques. The passpoints derived from the solution are then used as control for the mapping photography. Cross flights may be controlled by electronic means, by ground control, or by a combination of the two. When referring to electronically controlled cross flights precede the term with the pertinent label HIRAN, SHIRAN, or TPR.

(4) Grid flights are principally used in a HIRAN—TPR project intended for medium scale mapping. Grid flights are generally employed over large inaccessible areas where ground control is limited. These flights are at approimately right angles to one another forming a widely spaced grid pattern. Passpoints derived from these flights are used to control the mapping photography. The altitude of these flights is generally the same as the mapping photography but can be higher to decrease the number of exposures. It must be emphasized that electronically controlled grid patterns, cross flights, or TPR flights (properly spaced) are adequate for 1:250,000 scale mapping. In mapping at scales of 1:50,000 to 1:100,000, however, it is desirable that *each* photograph of the mapping photography be electronically controlled. Permissible deviations are described in paragraph 3-2*d*.

(5) Special flights may be required in certain areas. For example, infra-red film may be needed to improve the photographic image over certain woodland or coastal areas or an electronically controlled flight may be flown at a different altitude.

(6) If several areas within a project are to be photographed, the flight altitude above sea level is specified for each area.

(7) The sun angle or solar altitude must be such that long deep shadows in mountainous areas do not obliterate image detail from the mapping photography. Experience shows that the optimum solar angle for most conditions is approximately 45° above the horizon, and any departure from this value in either direction is a compromise. The optimum solar angle is not always practicable for a given area, however. In the polar regions the sun is never very high above the horizon. In flat desert areas, photographic missions flown during the middle of the day may be undesirable because of the heat waves reflected from the terrain. Heat waves cause light refraction, resulting in image distortion. Since the longest or most objectionable shadows appear at the lower solar altitudes, the SPD usually expresses the solar angles as a minimum in degrees. In flat areas of low contrast, however, the SPD may express the solar altitude as a maximum angle in order to provide better contrast. In still other areas, it may be necessary to specify the solar altitude as any angle that will produce photography with satisfactory detail and image definition acceptable to the field evaluator or photo inspector.

(8) The percentage of forward overlap and sidelap is as indicated in DIAM 70-6-1. Sidelap is normally 20 percent; however, in areas with extreme changes in terrain elevations the percentage of sidelap is increased to 30 percent, or more if warranted. Photography for photomaps normally has forward overlap and sidelap of 60-70 percent, and 30-40 percent respectively. In any event, the percentage of sidelap is alwasy indicated in the SPD for topographic mapping; both forward overlap and sidelap are indicated for the preparation of photomosaics.

(9) The diagram of the area to be photographed is a labeled drawing showing the geographic location, size, and shape of the area, and political boundaries, if any. Control flights may be plotted on this or on a separate diagram.

(10) The camera to be used must meet the requirements established by DIAM 70-6-1.

(11) The materials to be delivered to the requesting organization normally consist of: all original aerial negatives, one copy of a line index of all aerial photography obtained, and if electronically controlled photography is flown, UTM grid coordinates of each photo nadir point, TPR profile charts, and 35-mm film.

(12) Charts furnished—three copies each of the maps or charts covering the area are furnished to the photographic unit. The areas to be photographed, special flights, etc., are labeled on one copy of each map. The maps are listed on the last page of the SPD. Additional maps may be furnished to the photographic unit for the preparation of the flight map.

3-4. Flight Map

a. The flight map or plan, which is prepared by the photographic unit, shows the area to be photographed, and the position of each planned flight line, and indicates the altitude of the flights above sea level.

b. The SPD and accompanying charts furnished to the photographic unit contain the necessary information for the preparation of the flight map. The positions of any cross flights, special flights, or grid flights are shown on one of the accompanying charts. These flights are positioned in accordance with the control scheme and accuracy requirements for the mapping assignment. It is the photographic unit's responsibility to plot the flight lines of the mapping photography.

c. The following example illustrates the preparation of a typical flight map.

(1) The SPD for the project specifies:

(*a*) The camera to be used (KC-1B).

(*b*) Altitude of the photography (31,000 feet ASL).

(*c*) Flight direction of the mapping photography (east-west).

(*d*) Sidelap (20%).

(*e*) Size of area (50 miles north-south by 100 miles east-west).

(*f*) Chart or map with outline of area and other pertinent information (1:1,000,000 scale).

(2) Economical flight planning requires the minimum number of flight lines of mapping photography to cover the area and provide the sidelap specified by the SPD.

(*a*) To compute the distance between adjacent flight lines the following formula is used:

$$\frac{WP \times MS}{PS} = d$$

Where: d = Distance between each flight line on map

PS = Photograph scale (representative fraction)

WP = Width of photograph not covered by sidelap

MS = Map scale (representative fraction)

The SPD specifies the KC-1B camera (focal length 6″, 9″ x 9″ format) to be used at an altitude of 31,000 feet ASL. A study of the furnished maps indicates that the mean terrain elevation of the area to be photographed is 6,000 ft; therefore, the resultant photography would be at a scale of 1:50,000 (see fig. 1-3 for scale determination). The side lap as specified in the SPD is 20% which would provide an effective photograph width of 7.2 inches (80% of 9 in.). The scale of the map the flight lines are to be plotted on is 1:250,000.

By substituting values:

$$\frac{7.2'' \times \frac{1}{250{,}000}}{\frac{1}{50{,}000}} = 1.44''$$

Then 1.44 inches is the distance between flight lines on the map at 1:250,000 scale.

(*b*) To insure complete coverage of an area it is necessary to have all photos of the first and last flight overlap the boundary by 25 or 30 percent. To determine the position of the first flight line, the same formula as shown in (*a*) above is used (25% of 9 in. for the amount beyond the area).

By substituting values:

$$\frac{2.25 \times \frac{1}{250{,}000}}{\frac{1}{50{,}000}} = 0.45 \text{ inch}$$

Then 0.45 inch is the distance in from the project boundary the first flight line should be plotted.

(*c*) The number of flight lines necessary to cover a specific area is equal to $\frac{D}{d}$,

Where: D = width of area to be photographed, perpendicular to the flight lines

d = distance between flight lines

For example: D=50 miles or 12.67 inches and d being 1.44 inches between flight lines at the map scale; then by substituting values we have $\frac{12.67}{1.44} = 8.8$ as the number of flight lines required.

However, any fraction of a flight line must be considered a full flight. This means 9 flights are required to cover the area.

(3) The desired forward overlap is 56 percent which means that the forward gain or effective length would actually be 44 percent of the 9-inch picture. To determine the forward gain or distance between exposure stations on the plotted flight map the following formula is used:

$$\frac{PL \times MS}{PS} = m$$

Where: m = distance between photo centers (exposure stations)
PL = Effective length of phtograph
PS = Photograph scale
MS = Map scale

By substituting values:

$$\frac{3.96 \times \frac{1}{250{,}000}}{\frac{1}{50{,}000}} = .792$$

Then 0.792 inch is the forward gain or distance between photo centers in the direction of flight. With this information the number of photos required to adequately cover the area can be determined.

(4) To further insure adequate stereo coverage, add two photos to each end of each flight line. Then, to find the number of exposures in one flight, the following formula is used:

$$\frac{M}{m} + 4 = \text{total number of exposures}$$

Where: M = the map distance parallel to the flight lines (100 miles or 25.3 inches)
m = the map distance between photo centers (0.792 inch)

A flight line 25.3 (M) inches long with a distance of 0.792 inch between exposure stations would require:

$$\frac{25.3}{0.792} + 4 = 35.9 \text{ or } 36 \text{ exposures in one flight.}$$

(5) To find the total number of photographs required to cover the complete area, multiply the number of flight lines by the number of exposures in each line. A total of 324 photos will be required to cover the area for the above example.

CHAPTER 4
INSPECTION AND EVALUATION

4-1. Introduction

a. To insure that the photographic coverage is adequate, and that it meets the requirements for the mapping project, field inspections are performed while the project is in progress. Such on-the-spot inspections can uncover serious deficiencies before the photographic crew leaves the area to be photographed.

b. In determining the general acceptability of any series of aerial photographs, the type of photogrammetric equipment, cameras, and aircraft may be considered as relatively fixed, while other factors such as time, cost, accuracy, completeness, operating conditions, and flight hazards may be considered variable. Under combat conditions, one factor or another may be dominant, but the basis for judgment remains the specific purpose for which the photography is required and whether a particular series of aerial photographs effectively satisfies that purpose.

c. Experience has demonstrated that field inspection of aerial photography helps to bridge the gap between the standard written specifications and the effective use of the photography. Although the specifications for cartographic aerial photography (DIAM 70-6-1) together with the Specific Project Data, define the requirements which will assure an adequate map or chart compilation, these specifications cannot always anticipate field operating conditions. Poor weather conditions, enemy action, or partial equipment failure are a few of the factors which may contribute in whole or in part to the flying of substandard photography. Since the term "substandard" can include photography which ranges from only slightly deficient to totally useless for mapping or charting purposes, competent analysis must differentiate between what must be rejected and what may be salvaged. When the photography is inspected and evaluated, various factors and conditions are weighed and necessary reflights are performed while the photographic unit is still based in the area of operations.

d. The photographic evaluation team is organized in accordance with orders issued by the service controlling the mapping agency. Army and Air Force TOE's, Advance Base Components, and Equipment Allowance Lists designate the personnel and equipment authorized. In some cases evaluation teams consist of civilian technicians employed for this purpose.

4-2. Procedures

a. A review of the SPD and flight diagram by the inspector and the flight commander is made prior to any actual flying of the photography, to determine if they are consistent with local operating conditions. The photo inspector must be familiar with photogrammetric procedures, especially aerial triangulation, before he inspects any photography. The inspection team serves as a vital link between the requesting agency and the photographic unit. Liaison is maintained through progress reports and coverage diagrams at frequent intervals as required by the requesting agency. As the flying progresses, modifications to the SPD may be warranted, owing to local circumstances, in order to procure acceptable photography within the allotted time. When a change to the SPD affects the mapping plans or control requirements, the approval of the requesting agency must be obtained before any deviations are made. On the other hand, the photo inspector has the authority to make changes to the SPD if photogrammetric procedures are not affected.

b. The actual inspection of the photographic product may be accomplished in a number of ways, depending on conditions and the personnel and facilities available. Generally the inspection may be divided into four phases, with phase one and two interchangeable. When sufficient personnel (normally three people) are available, two or more phases may be performed at the same time. The items contained in DD Form 1516 (Aerial Photography Inspection Record) (appendix D) are completed for each roll of film, and for the inspection phases described in (1) through (4) below.

(1) The first inspection phase may be of the film itself for defects caused before and during processing. Camera malfunctions or careless handling practices may then be detected and rectified. The procedure to be followed in inspecting film is to place the roll film on a film viewer, emulsion up, being careful not to touch the emulsion. The film is inspected for excessive cloud or snow cover, objectionable shadows, proper exposure and processing, contrast, fog, stains, spots, dry marks, scratches, and streaks. Appendix C describes in detail the causes and prevention of negative film defects. Spot checks are made with a densitometer of the exposed negatives to assure conformance with the minimum and maximum density values specified in DIAM 70–6–1. Differential changes in the film base are checked by measuring the distances between opposite fiducial marks and comparing them with the camera calibration certificate. During this inspection phase exposures are selected for use in the third phase, the stereoscopic examination. Acceptance of film at this stage is tentative pending completion of the stereo check in phase three and evaluation of the photography in phase four.

(2) The second inspection phase, inspection of contact prints prepared from the processed film, is made to determine the suitability of the aerial photography for mapping purposes and its conformity to the specific requirements. The prints are examined for crab, tilt, conformity to flight line, side lap and forward overlap. The procedure usually followed is to lay out the contact prints in order of flight and inspect them for adherence to the requirements outlined in the SPD and DIAM 70–6–1. A transparent film template (fig. 4–1) the same size as the photographs may be prepared as an aid in determining the percentage of forward lap and side lap and degree of crab.

(*a*) Side lap is checked by laying out adjacent strips of photos for examination. The side lap for the entire project must average the amount specified in the SPD, and in no case will it be less than 10%.

(*b*) The amount of overlap between successive exposures may be determined with the aid of the template. This is accomplished by placing it over the area covered by both photographs and then reading the amount covered by the overlap.

(*c*) The degree of crab is determined by orienting the template over the photograph and measuring the angle of swing. Swing is the rotation of the photograph in its own plane about the camera axis. The angle formed by the line through the leading and trailing fiducial marks and the line of flight is the degree of crab. Crab in excess of 10° as measured from the line of flight is unacceptable.

(3) The third inspection phase, the stereoscopic examination, is made with a stereoplotting instrument (usually multiplex) to check the quality of selected exposures on the film roll. Diapositives are prepared from the negative film and observations are made with the stereoplotting instrument to determine negative quality regarding warpage, distortion, parallax elimination, the ability to "carry over" points to the adjacent models and definition of model images. Representative exposures are selected to provide stereo models. Three exposures (or two models) are selected near the ends of each roll to test the "carry-over" of pass points from one model to the other. If conditions warrant, a third "carry-over" test can be made near the center of the roll, and additional exposures can be added to any of these models to give a longer extension to perform a more detailed analysis. Following is a guide for the selection of exposures for the roll (stereo) test.

(*a*) On exposures that will produce models with long shorelines, at least 66 percent of the model should be land mass. Shorelines giving a triangular base on which to level are highly desirable.

(*b*) Exposures of the following types of areas are also desirable: areas with meandering streams and rivers or with canal developments; areas having relatively flat portions, such as large rice paddies, marshes, swamps, and wide river valleys; extensive cultural areas having some of the above features.

(*c*) For the density test, the test exposures should be representative of the worst in the flight. Dense or thin negatives throughout the flight generally have the same comparative density. Exposures having discolorations and excessive denseness, thinness, flatness, and contrast are selected. Exposures of well developed areas, or of areas having intricate hypsography, produce models suitable for evaluating the amount of detail that can be defined.

(*d*) For evaluation of damaged negatives the test exposures should represent the worst that can be found in the flight. These exposures are selected in conjunction with the exposures selected for tests for distortion, parallax elimination, etc. Representative exposures selected for examination of negative damage should include exposures with such defects as scratches, water spots, pinholes, bubbles, stains, and dirty emulsion.

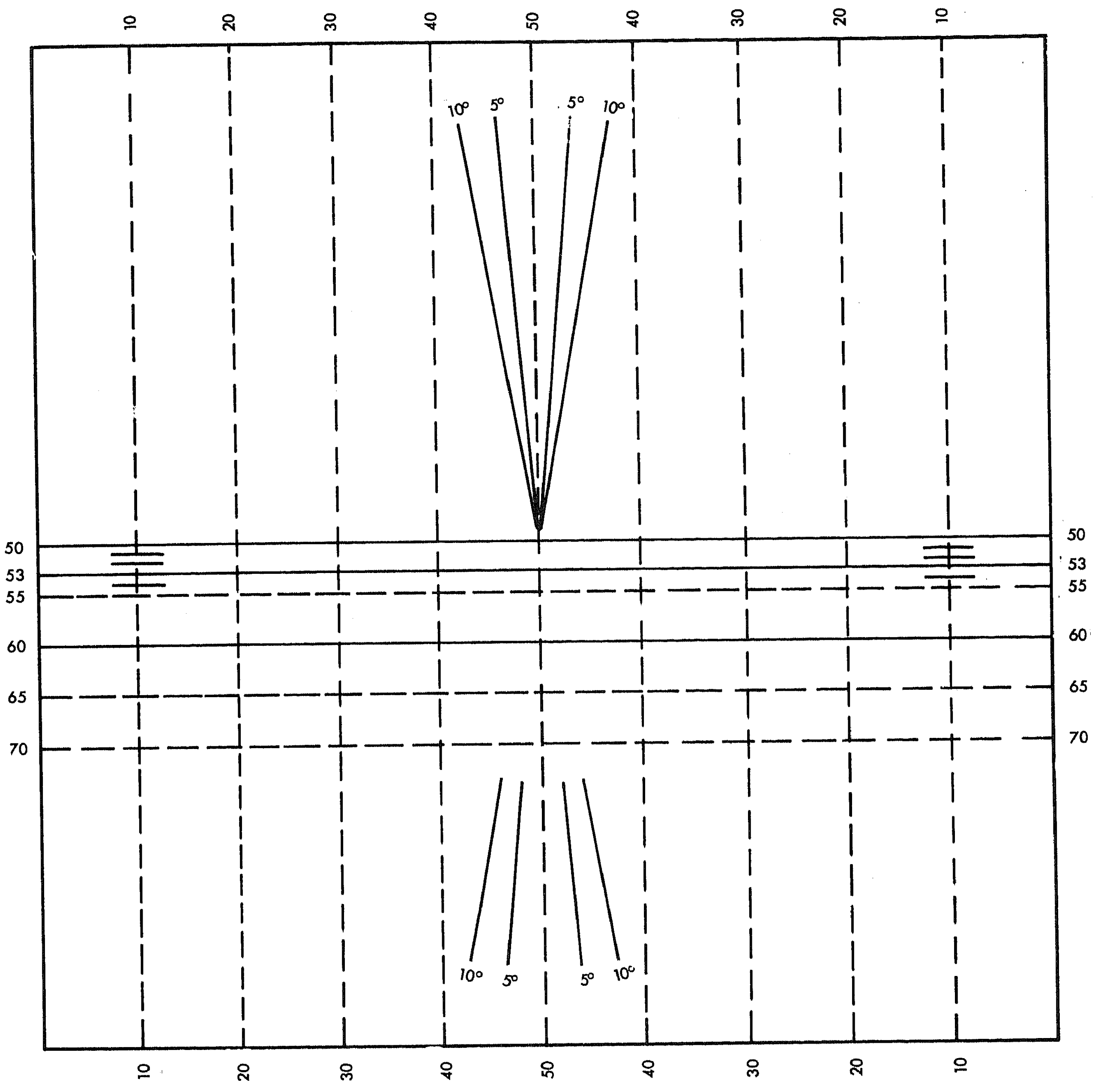


Figure 4–1. Overlap and crab template.

(*e*) After selection of the exposures to be used, diapositive plates are made. The diapositive plates should be inspected to assure that they are of a quality equal to the best that can be expected from the film.

(*f*) The diapositives to be tested are placed in the multiplex instrument for the stereo check. Orientation is accomplished by leveling on available control or on such natural features as lakes, shoreline, meandering streams and rivers, or relatively flat areas. The models are then examined for incongruous hyposography, visible warpage of the model, and parallax that cannot be eliminated. The quality of the diapositives is examined to assure that proper density can be obtained to accurately define detail.

(*g*) If no defects are found in any of the models tested, it is assumed that the remaining exposures of the roll are acceptable. If all the models tested are distorted, the entire roll may be rejected. However, where one or two models are rejected, and the remaining models are free from defects, it is necessary to make additional tests in order to isolate the rejected portion of the roll.

(4) The fourth and final phase of the inspection and evaluation procedure is the analysis of

the data obtained throughout the inspection. The acceptance or rejection of the photography is based on this analysis. The economy and success of an operation depends upon the soundness of the judgment used in the final analysis The rejection of unsuitable photography at this time makes it possible to obtain suitable reflights while the photographic unit is still in the area of operation. On the other hand, expensive reflights can be eliminated by the acceptance of marginal photography that satisfies the mapping requirement despite certain deficiencies. The evaluation team represents the requesting activity on all technical matters incident to the accomplishment of the photography. It has the final authority to accept or reject aerial photography and to modify project specifications when justified by local operating conditions.

c. *Aids Used for the Evaluation Process.*

(1) *Progress report charts.* These are small scale maps or charts, 1:1,000,000 scale, on which the photographic unit indicates the progress of the photographic coverage to date. On these charts the flight lines are shown by a single line with the first and last exposure indicated by a tick. The ticks are labeled with the exposure number and roll number. It may not always be practical to prepare a line index for a large project area. In such cases, a "block diagram" is prepared on an overlay keyed to a small scale map of the area. The area covered by the photography is filled in solid, usually in a translucent color. A copy of the progress chart, prepared by either method, is forwarded biweekly to the appropriate unit or agency along with a narrative report.

(2) *Reports.* Periodic reports are written by the inspector in connection with the evaluation of photography and dissemination of information to the mapping units concerned. Normally these reports are submitted biweekly. The purpose of the report is to—

(*a*) Serve as official notification of acceptance or rejection of aerial photography.

(*b*) Authenticate modifications or amendments to the specifications or SPD.

(*c*) Present a summary of work accomplished during the period reported.

(*d*) Report unusual incidents whether of a personnel nature or related to the project.

(3) *Project log.* The project log is required to record data vital to the mapping agency and serves as a full report of the daily activities of the photographic evaluation team. The project log should be divided into three parts. The first part should record pertinent data on the operations, the second part should record the daily activities, and the third part should consist of an annex containing copies of reports and records.

(*a*) The data to be recorded in the first part should include:

1 Names and grades of personnel assigned as evaluators.

2 Names and grades of staff officers and pilots of the photographic squadron.

3 Number and type of aircraft assigned to the project.

4 Description of cameras assigned to the project showing: type of camera, serial number of camera, lens number, magazine number, camera calibration report, and date camera was service tested.

5 Facilities available at the operational base such as photo laboratory, housing, messing, etc.

6 Any other information which, in the opinion of the recorder, would be of value to personnel engaged in future operations in that area.

(*b*) The second part of the project log, the recording of daily activities, should include—

1 Entries on travel of personnel.

2 Summary of work accomplished daily.

3 Amount of supplies utilized.

4 Notes on condition and functioning of equipment.

5 Unusual incidents.

6. Statements on the health and morale of personnel.

7 Description of any incidents or any statement which, in the opinion of the recorder, should be made a matter of record.

(*c*) The third part of the project log should include—

1 Original copies of the inspection forms.

2 Copies of all reports.

3 Copies of orders, correspondence, instructions, and other documents which pertain to the project.

(4) *Wall chart.* Although not required for reporting purposes, a wall chart, at a scale of 1:1,000,000 and large enough to cover the entire photographic area, is an invaluable aid. On this wall chart all the previous photography is plotted, and, as new flights are flown, the current photography is added. Thus the progress in the entire area may be seen at a glance.

4–3. Titling

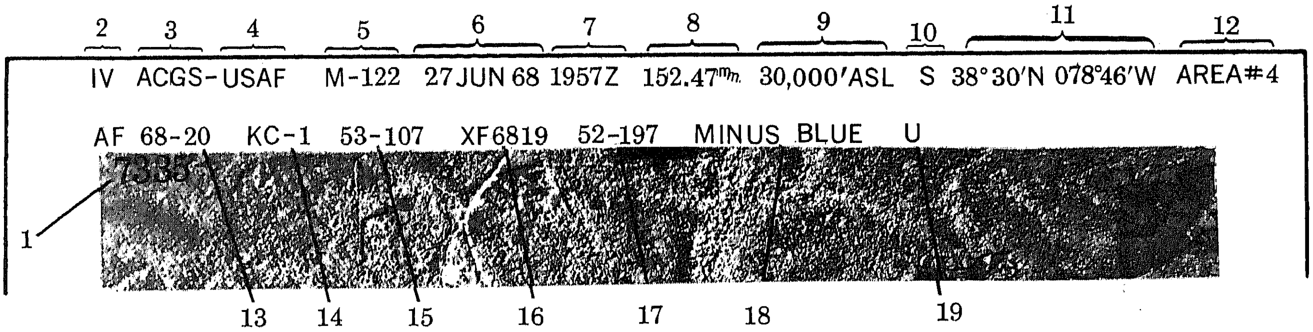
a. Titling, for the purpose of this TM, means both manual and mechanical labeling of each exposure or lengths of aerial film and electronic sensor imagery. DIA manual 55–5 presents the Department of Defense standardized procedures and specifications for the forwarding, titling, and plotting (indexing) of aerial photographs, electronic sensor imagery and related information. The following paragraphs explain the use and interpretation of titling information on aerial photographs.

b. Titling information is located on the film base, i.e., glossy surface of the film. The leader and trailer of each roll of film and the ends of each strip provide more complete information than the individual exposures. The additional information at the ends of each strip and on the leader and trailer of each roll of film applies to each exposure of that particular strip, but since it is seldom required by the user of the contact prints it is not shown on each negative.

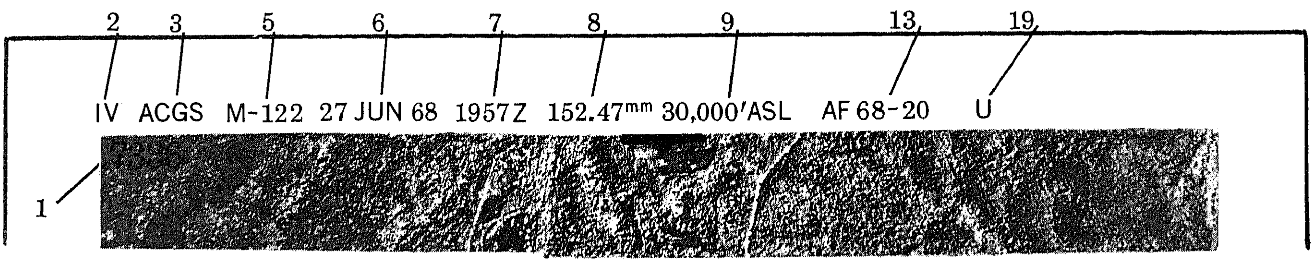
c. Figure 4–2 illustrates the titling of the first and second photographs of a typical flight. The identifying numbers are keyed to the list below. Special notations are sometimes required, in addition to those shown in figure 4–2. Any additional information for local purposes is shown following item No. 18. In all cases, the security classification, item No. 19, is last in the title block. Definitions are not included for items that are self-explanatory.

Item 1—Exposure number. Each exposure is numbered consecutively, starting with roll one. Exposure numbers are not repeated in a project.

Item 2—Camera position (location in aircraft). The letter V is used to indicate photographic coverage from one or more vertical cameras tilted (unintentionally) less than 5° from the vertical. The letter V is preceded by a numeral to indicate which vertical camera is used; i.e., 1V to show the first vertical camera, and 2V to show a second vertical camera.



FOR LEADER AND TRAILER OF EACH ROLL
INCLUDING ENDS OF EACH FLIGHT



FOR INDIVIDUAL EXPOSURES
(OTHER THAN THE ABOVE)

Figure 4–2. Film titling examples.

Item 3—Taking unit (organization).
Item 4—Service.
Item 5—Sortie/mission number
Item 6—Date of photograph.
Item 7—Time (Greenwich Mean Time (GMT) or Z). Time denotes beginning of the flight.
Item 8—Focal length of camera. Focal length is shown in inches, centimeters, or millimeters.
Item 9—Altitude. Shown in feet or meters above sea level.
Item 10—Kind of photography or imagery. One of the following symbols is used to show type of photograph.

(*a*) C—Charting, less than 1st order mapping and survey.

(*b*) R—Infrared optical.

(*c*) S—Surveying and mapping (1st order accuracy).

(*d*) SH—Surveying and mapping, electronically horizontal controlled.

(*e*) SHV—Surveying and mapping, electronically horizontal and vertical controlled.

(*f*) SV—Surveying and mapping electronically vertical controlled.

(*g*) X—Experimental.

Item 11—Geographic coordinates (only on leader, trailer and each end of the flight).
Item 12—Descriptive title, if applicable (identifies place or the subject of photography).
Item 13—Project name and/or number.
Item 14—Camera type and serial number.
Item 15—Lens cone serial number (if any).
Item 16—Lens type and serial number.
Item 17—Magazine type and serial number.
Item 18—Type of photographic filter used.
Item 19—Security classification.

d. Digital Data Photographic Recording. Certain photographic systems have been designed or adapted for automated information storage and retrieval. The Department of Defense has established a format for this method of data recording, which consists of a Code Matrix Block (CMB), a pattern of dots in block form recorded on the film simultaneously with sensor operations. The CMB provides coded information pertaining to the location and orientation of the photography, and other titling data. When DOD requirements specify that a photographic project shall incorporate the CMB method of recording data, the specifications for the project will provide the necessary instructions for implementing the requirement.

4-4. Indexing Photography

Indexes or plots show the relationship of each exposure to the others and to the project as a whole. Two types of indexes are ordinarily used, the line index or plot, and the photo index.

a. The line index, prepared by the photographic unit after the project is completed, consists of an overlay, usually keyed to a 1:250,000 scale map of the area, containing plotted lines showing the location and identification of the flights. Sometimes each picture, with its designating number, is plotted as a small square to scale. For most purposes, the exposure numbers shown at the beginning and end of each flight line are sufficient. If a break occurs in the flight, the exposure numbers at each break are shown on the chart. Gaps in photographic coverage are indicated graphically and clearly labeled. An explanatory legend is included in the margin. DIAM 55-5 contains detailed instructions for the plotting of a line index.

b. Photo indexes are prepared after the photography is flown and accepted. In certain instances they are required as part of a project and the SPD specifies that the photographic unit prepare and furnish them with the aerial negatives. Usually, however, they are prepared by the requesting agency after receipt of the accepted aerial negatives. Contact prints made from the negatives are assembled, matched, and stapled to a board in approximately correct relationship. Identifying numbers are usually pasted or stamped in the print corners. The assembly is then photographically reduced and a print from this negative constitutes the photo index. This type of index is useful for reconnaissance, area studies, control planning, field classification parties, geodetic control parties, for indicating progress in map compilation by production elements, and for ready location of specific photographs. A legend is shown on the index to explain location, roll numbers, dates of photography, flight altitudes, type and focal length of camera, and other pertinent information.

APPENDIX A
REFERENCES

1. Defense Intelligence Agency Publications

DIAM 70-6-1	Mapping, Charting, and Geodesy Operational Surveys.
DIAM 55-5	Aerial Photography and Airborne Electronic Sensor Imagery (Forwarding, Titling, and Plotting).

2. Department of the Army Publications

DA Pam 310-3	Index of Doctrinal, Training, and Organizational Publications.
FM 5-146	Engineer Topographic Units.
FM 21-26	Map Reading.
TM 5-239	High Precision Military Stereoplotter.
TM 5-240	Map Compilation, Color Separation, and Revision.
TM 5-244	Multiplex Mapping.
TM 30-245 (AFM 200-50)	Image Interpretation Handbook.
TM 30-246	Tactical Interpretation of Air Photos.

3. Department of the Air Force Publications and References

AFM 95-13	Precision Photographic Processing.
AFR 23-35	Catographic Photography and Geodetic Survey Services.

4. Related Texts

Manual of Photogrammetry (3d Edition), American Society of Photogrammetry, Banta (1965), Menasha, Wis.

Electronic Surveying and Mapping; Simo H. Laurila, (1966), Farrar Publishing Co., Washington, D.C.

APPENDIX B
SAMPLE SPD

U.S. ARMY TOPOGRAPHIC COMMAND

Revised 13 August 1968

SPECIFIC PROJECT DATA

Project Name and Number:	LIBERIA—AF67-4
Photography to be obtained:	1. MAPPING PHOTOGRAPHY 26,805 square miles of mapping photography of the area designated on the AREAS TO BE PHOTOGRAPHED sheet and outlined in blue on the maps furnished. 2. HIRAN MAPPING PHOTOGRAPHY 10,800 square miles of HIRAN mapping photography of the areas designated on the AREAS TO BE PHOTOGRAPHED sheet and outlined in blue on the maps furnished. 3. HIRAN CROSS FLIGHTS 1,970 linear miles of HIRAN cross flights. The locations of the cross flights are marked in red on the maps furnished and indicated on the HIRAN CROSS FLIGHTS sheet.
Mapping Photography:	*AREA 1.* Area: 26,805 square miles Flight Direction: North-South
HIRAN Mapping Photography:	*AREA 2.* Area: 9,875 square miles Flight Direction: Parallel to the mean azimuth of the coastline. *AREA 3.* Area: 925 square miles Flight Direction: North-South
Priority:	Weather permitting, the areas shall be accomplished in the following order: First Priority—Areas 2 and 3 Second Priority—Area 1 Third Priority—Reflight coverage over existing KC-3 photography.
Flight Altitude:	1. Area 1—21,500 feet above sea level with KC-1B and KC-8 cameras or 13,000 feet above sea level with RC-9 camera. 2. Areas 2, 3 and Cross Flights—21,500 feet above sea level with KC-1B and KC-8 cameras.
Flight Plan:	1. MAPPING PHOTOGRAPHY *a.* The flight plan shall be prepared by the photographic organization. The number of flight lines shall be the minimum required to cover the areas and provide the sidelap specified below.

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b. A rejected or broken portion of a flight line must be covered by a reflight which will overlap the end of the acceptable portion of the flight by a minimum of three exposures.

c. The flight lines must be continuous over a minimum of three HIRAN cross flights. However, whenever rejected exposures fall within an otherwise acceptable flight line then a reflight is permissible replacing the rejected exposures. The reflight must be flown in such a manner as to render the entire flight lines as one continuous, integral strip of cartographic quality photography, in the opinion of the TOPOCOM Field Evaluator.

2. HIRAN CROSS FLIGHTS
The HIRAN cross flights shall be flown as plotted on the 1:500,000 scale Liberia Planimetric Maps previously furnished.

Sidelap:	Average 25%
Solar Altitude:	Due to adverse weather conditions no minimum solar altitude is specified. However, the coverage obtained shall contain satisfactory detail and image definition in the opinion of the TOPOCOM Field Evaluator.
Cameras to be Used:	1. KC–8 and KC–1B Simultaneous dual camera operation shall be employed on each flight line. The KC–8 shall be mounted in the foremost mount and the KC–1B shall be mounted in the aftermost mount. 2. Wild RC–9 with Super Infragon Lens.
Film to be Used:	KC–8—Infrared stable base. KC–1B Panchromatic stable base. RC–9—Infrared stable base.
Indexing:	Each set of dual coverage shall be indexed as separate independent mapping photography. The simultaneously exposed rolls shall be given the same roll number except that the roll exposed with the aftermost camera shall carry the letter A after the roll number and on the film can label to denote it the Alternate Photography. The photography obtained with the foremost camera will be denoted as the Primary Photography.
HIRAN Data and Materials to be Furnished by TOPOCOM:	HIRAN station descriptions and coordinates, reconnaissance data and fixed tellurometer base line distances necessary for HIRAN photo requirement. The locations of the five HIRAN ground station sites are shown on the maps previously furnished.
Materials to be Delivered to TOPOCOM:	All acceptable original aerial negatives and one copy of a line index of all areas photographed. UTM coordinates for each HIRAN controlled exposure. (In the event that dual coverage is precluded by failure of one camera while on flight line the film from the operating camera, if acceptable shall become the Primary coverage).

U.S. ARMY TOPOGRAPHIC COMMAND

HIRAN CROSS FLIGHTS
LIBERIA

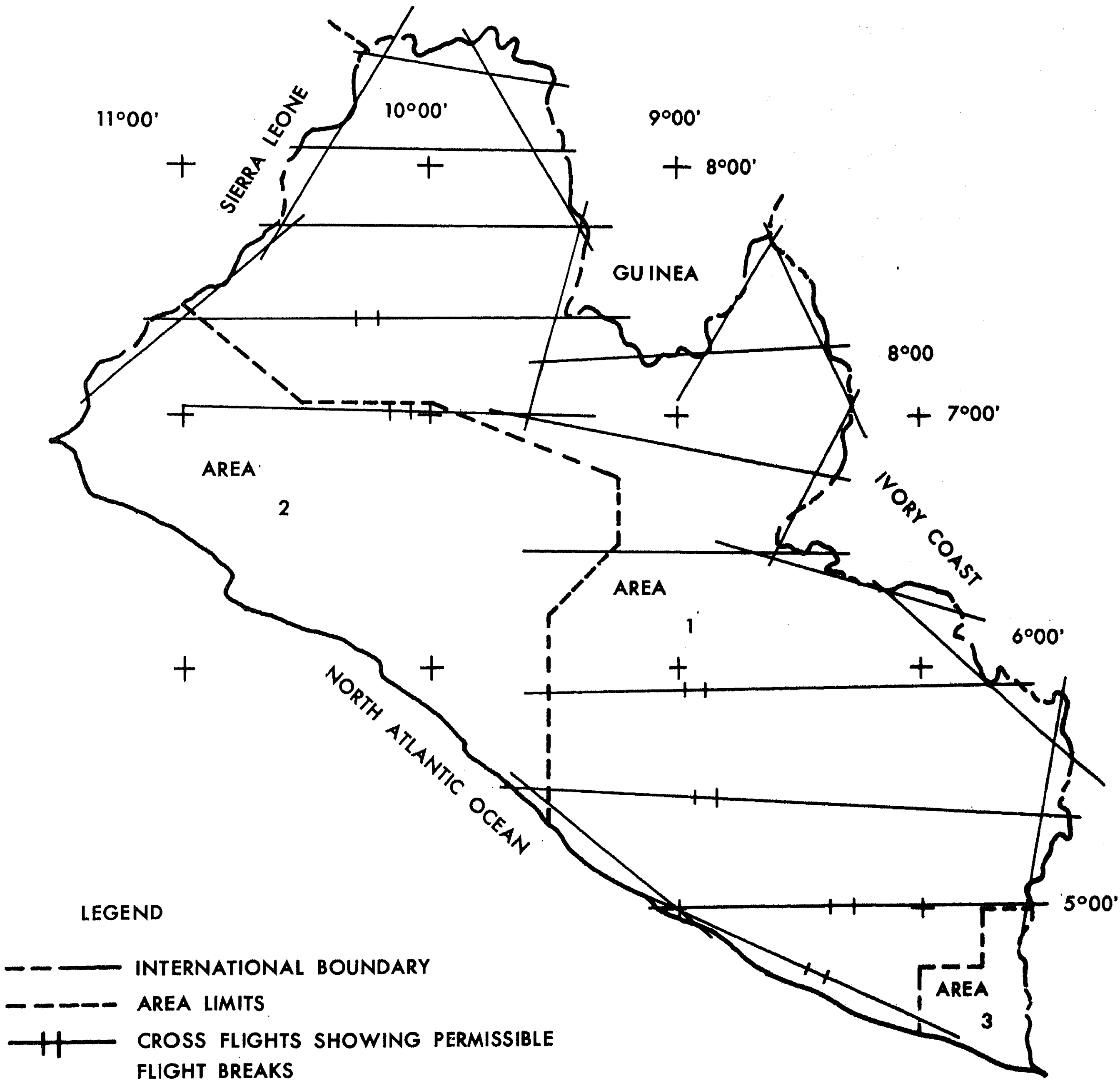

Figure B-1. HIRAN diagram.

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AREAS TO BE PHOTOGRAPHED
LIBERIA

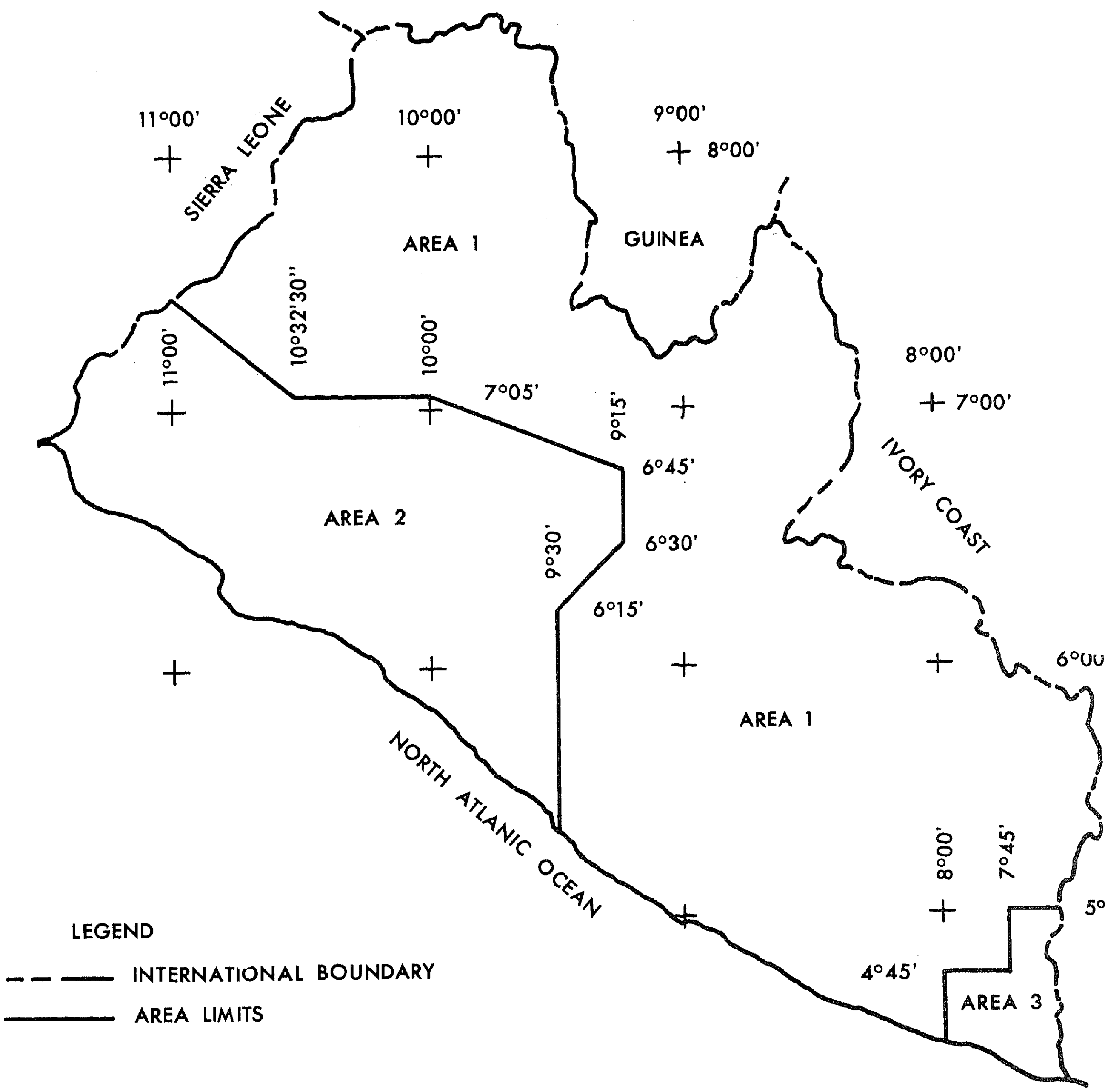

Figure B–2. Area diagram.

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MAPS TO BE FURNISHED

1. Three copies of the following have been previously furnished. The areas to be photographed, special flights, and HIRAN ground stations are labeled on one copy of each map.

Liberia Planimetric Maps 1:500,000 Scale

Name
Liberia—East Half
Liberia—West Half

2. Three copies each of the maps listed below have been furnished unmarked.

World Aeronautical Charts, 1:1,000,000 Scale

Sheet No.	*Sheet name*
781	MILO RIVER
817	CAPE PALMAS
818	SHERBRO ISLAND

APPENDIX C
COMMON DEFECTS OF CARTOGRAPHIC AERIAL NEGATIVES

C–1. This appendix discusses the most common defects observed in aerial negatives. These may be caused by the condition of the film base or emulsion before exposure, faulty film processing, camera conditions, or improper treatment of the film. In table C–1, the photo evaluator will find the most common defects listed, together with their causes and possible prevention.

Table C–1. Negative Defects

		Description	Cause	Prevention
Blurred negatives	Overall	Halo effect sourrounding image points.	Condensation on lens	Fly low altitude runs before high altitude runs, or descend from high altitude at maximum of 1000 ft per 3 min.
		Double image	Vibration of camera	Cushion camera against plane vibration.
		Longitudinal streaks of image points parallel to flight lines.	Movement of image	Use proper shutter speed for low altitude and speed of plane.
			Plane altitude near hyperfocal distance of camera.	Maintain plane altitude beyond hyperfocal distance of camera.
		Image out of focus (most likely to occur at large lens apertures).	Incorrect setting for type of film, or correct setting altered during camera repairs.	Correct setting. Repair and correct camera.
		Fog-overall or local veiling resulting in low contrast; whites are a dirty grey.	Overage film, impure developer, forced development, improper safelight, dirty lens. Overexposure, often combined with under-development.	
	Localized	Local blurring (part blurred, remainder sharp). Wavy image.	Failure or partial failure to vacuum (camera). Dirt on platen or vacuum back, or objects preventing film from proper contact with pressure plate.	
Lack of sharpness		Poor definition of image (poor definition of lens).	Incorrect solar altitude. Terrain peculiarities. Use of incorrect filters.	
		Coarse graininess of negative (degree of visibility of silver grains of developed negative as determined by the relative size of the grains).	Inherent emulsion structure. (Fast film sacrifices fine grain for speed.) Type of developer. Length of development.	
Large areas of varying density		Longitudinal parallel areas of unequal tone.	Uneven development of negative. Overloading film capacity of developing unit.	
		Irregular areas of varying tone	Uneven development of fixation Negative partially immersed in developer or fixing bath.	Use ample chemical solutions to cover all of film.
		Large or small blank areas on negative.	Obstruction in front of camera	Keep camera front clear of obstructions.
		Rectangular grid pattern on negative	Moisture on film in a vacuum type camera back.	

Table C–1. Negative Defects—Continued

		Description	Cause	Prevention
Small spots or streaks		Light spots appear on prints in shape of water drops.	Water spots drying on negative; moisture condensing on undeveloped film.	Adjust air squeegee or wiper blade to remove excess liquids.
		Dark spots on negative		Store film (undeveloped) in cool, dry spot.
		Small round white spots on negative or small round dark spots on prints.	Air bells on film preventing developer from acting on film.	Agitate film properly during development.
		Spots with diffused edges, often with tails	Incompletely dissolved developer chemicals sticking to film.	Mix chemicals properly and agitate film properly during development.
		Irregular clear spots	Scum from developer surface adhering to film, preventing access of developer to emulsion. Chemicals of solutions touching film before development.	Properly agitate film during development.
	Abrasion of film	Fine parallel or streaks on film (fine light parallel lines or streaks on print).	Abrasion of film by sharp objects during film rewind in camera. Abrasion of base side creates an opaquing effect.	Keep camera free of dirt and grit.
		Fine light lines or streaks on film (fine dark lines or streaks on print).	Abrasion of film after development Careless rolling and unrolling of film.	Handle film carefully.
		Clear irregular areas on film (dark irregular areas on prints).	Cuts, gashes, and tears in emulsion after development. Insufficient hardening, making emulsion soft and tacky. Rolling film too tightly on roll, causing soft emulsion to stick and pull when unwound.	Handle film carefully.
	Finger-marks	Fingermarks on film (1) Light (2) Dark.	(1) Fingers touching emulsion before development, or (2) developer-contaminated fingers touching film before development.	Avoid touching emulsion side of film.
Other	Miscellaneous	Dark streaks combined with general fog.	Camera leak or improper safelight. (If edges clear—camera defect.)	
		Branching or fan-shaped dark mark-on film.	Static electric discharges on dry film caused by dry friction during or after very dry, cold weather.	Handle film gently in cold, dry weather.
		Network of lines, grainy leather-like appearance.	Reticulated emulsion, caused by overage film, processing film without sufficient hardener, subjecting film to extreme changes in temperature while processing, or processing or drying film in excessively warm temperatures.	If caused by improper temperature during processing, maintain recommended temperatures while processing.
		Stretched and warped emulsion and backing.	Subjecting film to too much heat. Careless handling of film. Subjecting film to tension while titling.	
		Torn negatives	Old and brittle film. Deep scratches in film base. Jerking or forcing film over obstructions and bent spool. Crimping of film.	
		Frilling (separation of emulsion from base around edges).	Processing solutions excessively warm, or if wash water is warm and film is not properly hardened.	
		Blisters (appearing as small crater-like depressions in the emulsion).	Carbon dioxide gas liberated by chemical reactions of solution when temperature is above normal.	
		Creeping of emulsion	High temperature and insufficient ventilation during drying.	
		Fungus (usually appears in the gelatin backing).	Improper storage under warm, humid conditions.	

C-2. *Types of negative defects.* Defects in the negative can be divided into those that cause distortion in the negative, displacement of images, and poor image quality which affects the ability of the compiler to observe proper definition of detail.

a. Distortion. The presence of distortion in aerial negatives may be expected when any of the following conditions occur:

(1) Improper seating of the platen or failure of the vacuum to flatten the film.
(2) Tears.
(3) Scratches.
(4) Reticulation.
(5) Bubbles, pinholes.
(6) Sheen and other emulsion imperfections.
(7) Excessive heat during drying.

b. Dimensional Instability.

(1) Aerial negatives intended as the source of accurate measurements require a dimensionally stable film base. Dimensional stability of photographic film depends on many factors. These include not only the chemical composition of the film and the treatment it receives during manufacture and processing, but also the conditions under which it is stored before and after exposure. Dimensional changes that occur in photographic films are of two types, temporary and permanent.

(*a*) Temporary expansion or contraction is due to the loss or gain of moisture by the film owing to humidity and temperature changes.

(*b*) Permanent shrinkage in photographic film is caused by loss of residual solvents and plasticizer from the base, plastic flow, and release of mechanical strain. In the types of film now being used these characteristics are almost negligible or, at least, held to a minimum when the film is carefully handled.

(2) Uneven dimensional changes caused by improper handling occur frequently. This condition usually is caused by winding the film too tight on the roll, subjecting the film to tension while titling, or similar improper handling.

(3) Differential shrinkage or expansion in the dimensional plane of the film affects the accuracy of mapping because it may produce distortion in both the film and the finished product. Such a defect cannot be compensated for by a simple change in magnification. Humidity or thermal expansion usually is greater in the widthwise than in the lengthwise direction of the roll. However, this condition usually does not cause enough differential change to cause rejection of the film. For the purpose of definition the line of flight direction of the film usually is referred to as the X or A-B distance, while the widthwise direction is referred to as the Y or C-D distance.

(4) Determination of negative stability is a part of the negative inspection procedure. Since these measurements should be made on exposures throughout each roll to give a good representation of that roll, they usually are made on the exposures selected for the roll (stereo) test. The X and Y distances are measured on the film to the nearest 0.01 millimeter, and are compared with the corresponding calibrated measurements as stated on the camera certificate. The differential change in dimension should not exceed 0.2 millimeter. However, other factors must be considered before final acceptance or rejection of the film. For example, when distortion and flatness tests provide satisfactory results, acceptable differential change in dimension may be as great as 0.5 millimeter. Great care must be taken to select water-land areas which permit a strong leveling solution when testing diapositives made from negatives with a differential change which exceeds 0.2 millimeter.

(5) When excessive differential changes are found, it is necessary to take additional measurements in order to isolate the portion of the film that is distorted.

(6) Table C-2 is an example of the data obtained during a typical test procedure.

Table C-2. Film Stability Test

Camera No. CA-14 No. 241, lens BF 1186R

During measurements: Temp. 70° Humidity 56%					
Exposure No.		Calibrated dimension	Measured dimension	Change	Differential change
18	X	227.06	227.36	+0.30	0.18
	Y	227.02	227.14	+0.12	
50	X	227.06	227.37	+0.31	*0.30
	Y	227.02	227.01	−0.01	
54	X	227.06	227.35	+0.29	0.16
	Y	227.02	227.15	+0.13	

*Exposure 50 has excessive differential change in film dimension.

c. Improper Definition of Detail. Defects which make the negative incapable of yielding good image definition are the result of defective film, incorrect exposure, improper processing, or improper storage. The two most common causes of poor image definitions are stains and improper density.

(1) *Negative stains.* Various types of stains do not necessarily appear immediately after processing, but may become evident only after storage.

(*a*) Yellow or brown stains may be caused by accumulated developer in an exhausted fixing bath, or by silver compounds left in the film by incomplete fixation or washing.

(*b*) Greenish or dichloric fog usually shows a metallic sheen by reflected light and a pinkish tint by transmitted light. It may be caused by impurities, such as hypo, in the developer, by the solution in the fixing bath, not having thorough access to all of the emulsion, or by prolonged treatment in exhausted developer.

(*c*) Brown spots may be caused by scum from oxidized developer, or from silver sulfide from the surface of the developer or fixing bath.

(*d*) Yellowish white opalescence is caused by finely divided sulfur, resulting from decomposition of hypo in the emulsion because of an excess of acid or a deficiency of sulfite in the fixing bath.

(*e*) Silvery white opalescence may be caused by washing the negative with alcohol and drying too rapidly in warm air.

(*f*) Yellow faded image is caused by a chemical change in the silier grains of the image to a form of silver sulfide from sulfur compounds left in the film by incomplete fixation and washing. It may also be caused by external sources, such as coal gases, reaching the film. The opalescence is more apt to occur with prints, but coasionally it is encountered with negatives.

(*g*) White crystalline deposits are caused by hypo left by incomplete washing. These usually appear several weeks after the film is dried.

(*h*) White, slight deposits are caused by sulfur from a decomposed fixing bath or suspended matter in wash water. These deposits often appear in the form of water spots.

(2) *Density.* Negatives should be so exposed and developed that they preserve all highlights and shadow detail. An acceptable roll of film should produce a minimum density of 0.3 and a maximum density of 1.5 (as measured with a densitometer having a scale range of 0 to 3.0). Table C-3 shows negative characteristics and the relationship between exposure and development as reflected in resulting density, shadow areas, highlights, and contrast.

Table C-3. Negative Characteristics

Exposure	Development	Density	Shadows	Highlight	Contrast
Under	Under	Very thin	Clear film no details	Weak	Insufficient
	Normal	Thin	Clear film no details	Weak	May be correct
	Over	May be thin	May be fogged	Weak	May be correct
Normal	Under	Thin	Thin; full of detail	Weak	Insufficient
	Normal	Correct	Clear; full of detail	Strong; full of detail	Correct
	Over	Too great	Veiled over, good detail	Heavy; some detail lost	Excessive
Over	Under	May be correct	Full of detail	Weak and flat	Lacking; below average
	Normal	Too great	Heavy; full of detail	Heavy; some detail lost	May be correct
	Over	Excessive	Heavy; some detail lost	Blacked out, no detail	May be excessive

C-3. Evaluation of Effect on Cartography

The accuracy of all photogrammetric measure ments depends on the quality of the aerial negatives from which the diapositives were made. Therefore, any negative defects that tend to distort, displace, or obscure the photo images must be evaluated to determine to what degree the accuracy of the measurements are affected. It is obvious that certain defects, such as torn negatives, very dense negatives, very thin negatives, negatives with reticulated emulsion, or warped negatives, are cause enough for rejection without further consideration. Other defects must be evaluated to determine if adequate cause for rejection exists. Only through stereoscopic examination by experienced evaluators can decisions be made as to whether or not the photography is suitable for stereophotogrammetric mapping purposes.

APPENDIX D

AERIAL PHOTOGRAPHY INSPECTION RECORD

D-1. Sample inspection record, DD Form 1516.

PROJECT NAME	PROJECT NUMBER	LOCATION	DATE(S)	LOG ROLL NUMBER
CHARLIE HORSE	44 - 7	FT. BELVOIR, VA	17 NOV 1968	15 NOV 75

FLYING ORGANIZATION: ACGS
FLIGHT ALTITUDE: 10,000 'ASL
PHOTO SCALE: 1 : 19,500
MISSION/SORTIE: 4

TYPE OF PHOTO: VERTICAL MAPPING
CAMERA TYPE - SERIAL NUMBER: KC-1B, 63-102
CAL FL: 152.404 MM
LENS NUMBER: 214/480
MAGAZINE NUMBER: 62 - 128
FINAL ROLL NUMBER: 15

NEGATIVE INSPECTION CHECK LIST

DEVELOPMENT ✓ = ACCEPTED × = REJECTED

	TEMP	TIME	GAMMA
B-5A	68°	18	1.2
FE-120			
HTA-3			
OTHER			

EXPOSURE NORMAL ✓ OVER / UNDER	
DEVELOPMENT NORMAL ✓ OVER / UNDER	
TYPE OF FILM TOPO / POLYESTER	✓ (POLYESTER)
SHARPNESS OF DETAIL	✓
LIGHT / DEVELOPMENT STREAKS	✓
PINHOLES / SCRATCHES / ABRASIONS	✓
CHEMICAL STAINS OR WATER MARKS	✓
STATIC MARKS	✓
VACUUM LIGHT	X
ADEQUATE LEADER AND TRAILER	✓
DATA CHAMBER INFORMATION	✓
DAMAGED FILM	✓
CAMERA / MAGAZINE MALFUNCTION	X

CLOUDS, SHADOWS AND ADDITIONAL REMARKS: EXP. 98 thru 134

INSPECTED BY: John Smith
DATE INSPECTED: 19 Nov 68

FINAL INSPECTION

NUMBERING: OK
TITLING: OK
FINAL FILM LOG: OK
REMARKS: CAMERA REPAIR SECTION ADVISED OF NON FUNCTIONING VACUUM LIGHT.
INSPECTED BY:

FLIGHT LINE	COORDINATES BEGIN LAT	BEGIN LONG	END LAT	END LONG	BOUNDARY COVERAGE N	S	E	W
83	38° 45'	77° 30'	38° 45'	76° 55'			✓	✓
85	38° 43'	76° 54'	38° 43'	77° 31'			✓	✓
84	38° 41'	77° 30'	38° 41'	76° 56'			✓	✓
82	38° 39'	76° 54'	38° 39'	77° 31'			✓	✓
86	38° 37'	77° 30'	38° 37'	76° 55'			✓	✓

FLIGHT LINE	HEADING	EXPOSURES BEGIN	EXPOSURES END	FORWARD LAP MAX	FORWARD LAP MIN	SIDELAP TO N OR E MAX	SIDELAP TO N OR E MIN	WITH LINE	NUMBER OF EXPOSURES ACCEPTED	NUMBER OF EXPOSURES REJECTED	LINEAR MILES ACC	LINEAR MILES REJ	FINAL EXPOSURE NUMBERS	REASON REJECTED AND REMARKS
83	EAST	1	25	60	55	25	10	84	25	—	30		1977-2002	
85	WEST	27	54	58	53	23	8	86	28	—	30		2003-2031	LOW SIDELAP ACCEPTED
84	EAST	56	78	62	57	30	15	85	23	—	30		2032-2055	
82	WEST	80	107	59	51	32	17	83	26	2	28	2	2056-2084	FORWARD LAP GAP
86	EAST	109	134	58	54				26	—	30		2085-2111	

DD FORM 1516, 1 APR 66 — REPLACES EDITION OF 1 JAN 65 AND DD FORMS 1517 AND 1518 WHICH ARE OBSOLETE. AERIAL PHOTOGRAPHY INSPECTION RECORD

LINE NO	LAPPING EXP	LAPPED EXP	FORWARD LAP (%)	TRIP (%)	WITH EXP	LINE NO	LAPPING EXP	LAPPED EXP	FORWARD LAP (%)	TRIP (%)	WITH EXP
82	84	83	51	2-10	82						
82	85	84	51	1-10	83						

LINE	EXPOSURE THRU EXPOSURE	WITH FLIGHT	LINE	EXPOSURE THRU EXPOSURE	(%) SIDELAP
85	2013-2014		86	2101-2102	8-10

EXPOSURE	A-B DIST	C-D DIST	DIFF
STANDARD	238.205	235.184	± 00 MM
14	238.100	235.100	-.029
15	238.100	235.100	-.029
16	238.100	235.100	-.029
127	238.150	235.140	-.011
128	238.150	235.140	-0.11
129	238.150	235.140	-0.11

FLATNESS

Good

PARALLAX ELIMINATION

Good

EVIDENCE OF DISTORTION

none

STEREO TEST DATA

DIAPOSITIVE PRINTER NUMBER

EA- 06

STEREO TEST BY OPER

John Smith

DATE OF TEST

21 Nov 68

	+.1	
+ 14	+ 15	+ 16
	-.1	

	+.2	
+ 127	+ 128	+ 129
	+.1	

+	+	+

D-2. Reverse side, DD Form 1516.

APPENDIX E
CALIBRATION OF AERIAL CAMERAS

E-1. Need for Tests

The purpose of an aerial survey is to gather topographic information in a distortionless perspective to be used in stereoscopic plotting instruments. To insure that suitable precision cameras are used on aerial surveys, a series of tests are required to evaluate the cameras. The first two tests are concerned with the optical-mechanical characteristics of the camera and usually are called the camera calibration test and the platen flatness test. The third test is concerned with how the camera will operate over the project area; that is, the mechanical functioning and the ability of the camera to yield correct geometry throughout the focal plane. This test is called the service test.

E-2. Camera Calibration Test

a. The camera calibration test is necessary to certify the fulfillment of the requirements set forth in the manufacturing specifications for new cameras. Any cameras which undergo any repairs that affect the optical-mechanical relationship of the camera must be calibrated.

b. The camera characteristics examined during this test include all optical items set forth in specifications for the camera. Therefore, this test records data vital to the photogrammetrist.

c. A few organizations have the facilities for making this type of test. Among these are the National Bureau of Standards, the Fairchild Camera and Instrument Corporation, and the U.S. Geological Survey. Camera calibration reports made by these organizations should be obtained by the mapping or charting unit and by the photographic unit having possession of the cameras that are to be used on cartographic mapping assignments.

d. To the photogrammetrist, the camera calibration report is a qualitative certificate of camera performance characteristics and a numerical record of these characteristics to be used in determining the suitability of the camera for use with precision stereoscopic mapping instruments. Figures E-1 and E-2 show examples of the data presented in a camera calibration report. Notice that this report *is not* a certificate that the camera passes specifications. This report merely presents the results of the test, from which it can be determined if the camera characteristics are within specified values.

e. Circumstances may develop where a camera not meeting specifications may inadvertently be placed in service. Therefore, in order to insure that all cameras used on a mapping project are suitable as precision mapping cameras, it is the responsibility of the photographic evaluator to compare the camera calibration reports with specifications for precision mapping cameras. This must be done for any cameras that have not been previously used and for cameras with which the evaluator is unfamiliar.

f. Under normal circumstances, the mapping unit and the photographic organization will have on file records of fitness for cameras being used on assignments.

E-3. Platen Flatness Test

A further test of the optical-mechanical characteristics of the camera is necessary to meet the requirements of the specifications. This test, the camera platen flatness test, is performed to check the overall focal plane surface of the platen. Specifications call for this surface to be flat, under operating conditions, to within ±.0005 inch. The test is conducted by introducing all operating stresses present at the instant of exposure, and the test readings must be recorded in such a way that the position and value of each test point are indicated. These readings must be accurate to within ±0.0001 inch. The platen tested must be positively identified by having the camera, cone, or magazine number of the unit permanently and irremovably marked on it. This identifying number should be noted on the report. Figure E-3 is an example of the recorded readings of a camera platen flatness test.

E–4. Service Test

Camera calibration tests leave many unknown factors in actual camera performance. Laboratory calibration usually is confined to the optical characteristics of the camera. There are no data available regarding the mechanical functioning of the cameras over project areas. This deficiency is met by another operation called a service test, which tests the ability of the camera to yield correct geometry throughout the negative focal plane, tests the capabilities of the camera in control bridging, and determines the ability of the camera to operate at the extreme variations in temperature and air pressure that will be encountered on the project.

CALIBRATION CERTIFICATE

Submitted By

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION
DEFENSE PRODUCTS DIVISION
SYOSSET, L. I., NEW YORK

April 2, 1963

Camera Type KC-1B

Camera No. 63-037

Lens and Cone No. 311

a) Make and Type Goerz Planigon

b) Nominal Focal Length 6 Inch

c) Maximum Aperture f/6.3

This Certificate applies to the above subject precision camera with lens as stated herein. It was tested at maximum aperture. All measurements were made with parallel light incident on the lens. The light source is white light, rated at 3500° K.

Figure E-1. Calibration certificate.

LENS NO. 311

CAMERA NO. 63-037

Date 4/2/63

I. FOCAL LENGTH

Flange Focal Distance	Equivalent Focal Length	Calibrated Focal Length
MM 138.608	MM 152.337	MM 152.311

The probable errors of these determinations of focal length do not exceed 0.025 mm.

II. DISTORTION

Average Distortion Referred to the Calibrated Focal Length

7.5°	15°	22.5°	27.5°	30°	32.5°	35°	37.5°	40°	42.5°	45°
+.003	.000	+.004	-.009	+.009	-.008	+.005	+.001	+.009	+.008	(+.005)

The values of the distortion are measured in millimeters and indicate the displacement of the image from its distortion-free position. A positive value indicates a displacement from the center of the plate. The probable error is approximately 0.005 mm.

Tangential Distortion

The Tangential distortion is 0.004 mm.

III. AVERAGE RESOLVING POWER

(Aerographic Film) **AWAR** 26.5

	0°	7.5°	15°	22.5°	27.5°	30°	32.5°	35°	37.5°	40°	42.5°	45°
Tangential	36	34	28	29	28	25	25	25	25	23	22	19
Radial	41	35	30	30	25	26	26	28	26	28	22	20

The values of the resolving power are given at specified intervals from the center of the field and are obtained by photographing suitable test charts comprised of patterns of parallel lines. The series of patterns of the test chart are imaged on the negative with lines per millimeter spaced from 4 to 129 in $\sqrt[6]{2}$ intervals.

The row marked "*Tangential*" gives the number of lines per millimeter in the image on the negative of the finest pattern of the test chart that is distinctly resolved into separate lines when the lines lie perpendicular to the radius drawn from the center of the field. The row marked "*Radial*" gives similar values for the pattern of test lines lying parallel to the radius.

Figure E-1—Continued.

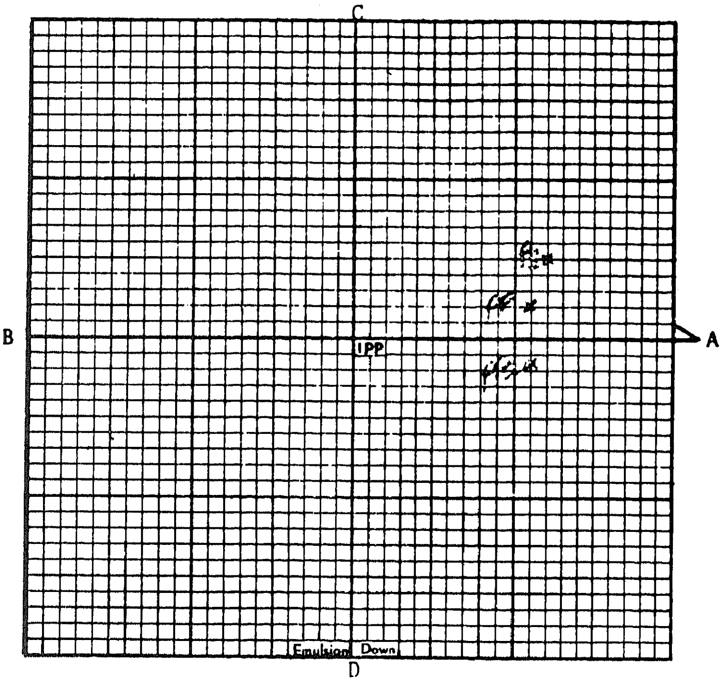
FAIRCHILD CAMERA AND INSTRUMENT CORPORATION
DEFENSE PRODUCTS DIVISION

LENS NO. 311 CAMERA NO. 63-037

Date 4/2/63

VII. INDICATED PRINCIPAL POINT

The positions of all points are referenced to the Indicated Principal Point (IPP) as origin with the straight line drawn between the A and B fiducials being coincident with the X- axis. The CD line goes through the origin but is not generally coincident with the Y- axis.



X_{ppa} = .022 mm
Y_{ppa} = .003 mm

X_{ps} = .024 mm
Y_{ps} = .010 mm

X_{pp} = .022 mm
Y_{pp} = .004 mm

Fiducial Positions

A_x = 120.435 mm
A_y = .000 mm

B_x = 117.394 mm
B_y = .000 mm

C_x = -.002 mm
C_y = 117.369 mm

D_x = +.002 mm
D_y = 117.585 mm

Legend:

X_{ppa} - Location on X- coordinate of Principal Point of Autocollimation.
Y_{ppa} - Location on Y- coordinate of Principal Point of Autocollimation.
X_{ps} - Location on X- coordinate of Point of Symmetry.
Y_{ps} - Location on Y- coordinate of Point of Symmetry.
X_{pp} - Location on X- coordinate of Principal Point.
Y_{pp} - Location on Y- coordinate of Principal Point. (As defined by Washer)

~~Figure 17—Continued.~~

Figure E-1—Continued.

LENS NO. 311

CAMERA NO. 63-037

Date 4/2/63

IV. CALIBRATION

The lines joining opposite pairs of collimation index markers intersect at an angle of 90° ±1 minute of arc, and their intersection indicates the location of the Point of Symmetry with a probable error not exceeding 0.05 mm. The departure of the principal point from the auto collimation point is 0.007 mm.

V. COLLIMATION MARKER SEPARATION

A - B ....237.829 mm ± 0.010 ....

C - D .....234.954 mm ± 0.010..............

Markers A and B lie in the line of flight.

The calibration of this camera was performed at a temperature of approximately 70° Fahrenheit.

VI. CALIBRATED FOCAL LENGTH MARKER SEPARATION

These marker separations are set at a distance equal to the calibrated focal length ± 0.010 mm

II-A. DISTORTION AVERAGE OF THE QUADRANTS.

The following table lists the values for distortion for each quadrant, the location of each quadrant being shown on the graph form. Thus, quadrants AC lies between the A and C fiducials on the diagonal of the format, BD between the B and D fiducials, etc. The values are in millimeters and the definitions for Table II, as seen on the previous page, apply.

Quad.	7.5°	15°	22.5°	27.5°	30°	32.5°	35°	37.5°	40°	42.5°	45°
AC	+.006	+.001	-.004	-.008	-.008	-.008	-.006	+.001	+.008	+.005	(-.012)
BD	.000	-.003	-.005	-.010	-.010	-.009	-.005	+.002	+.010	+.010	(+.002)
AD	+.003	+.002	-.003	-.009	-.009	-.008	-.005	+.002	+.010	+.008	(-.006)
BC	+.002	-.001	-.005	-.008	-.008	-.007	-.004	.000	+.007	+.007	(-.005)

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION
FAIRCHILD SPACE & DEFENSE SYSTEMS

Signed ____________
Precision Camera Calibration Laboratory

Syosset, L.I., New York

Figure E-1—Continued.

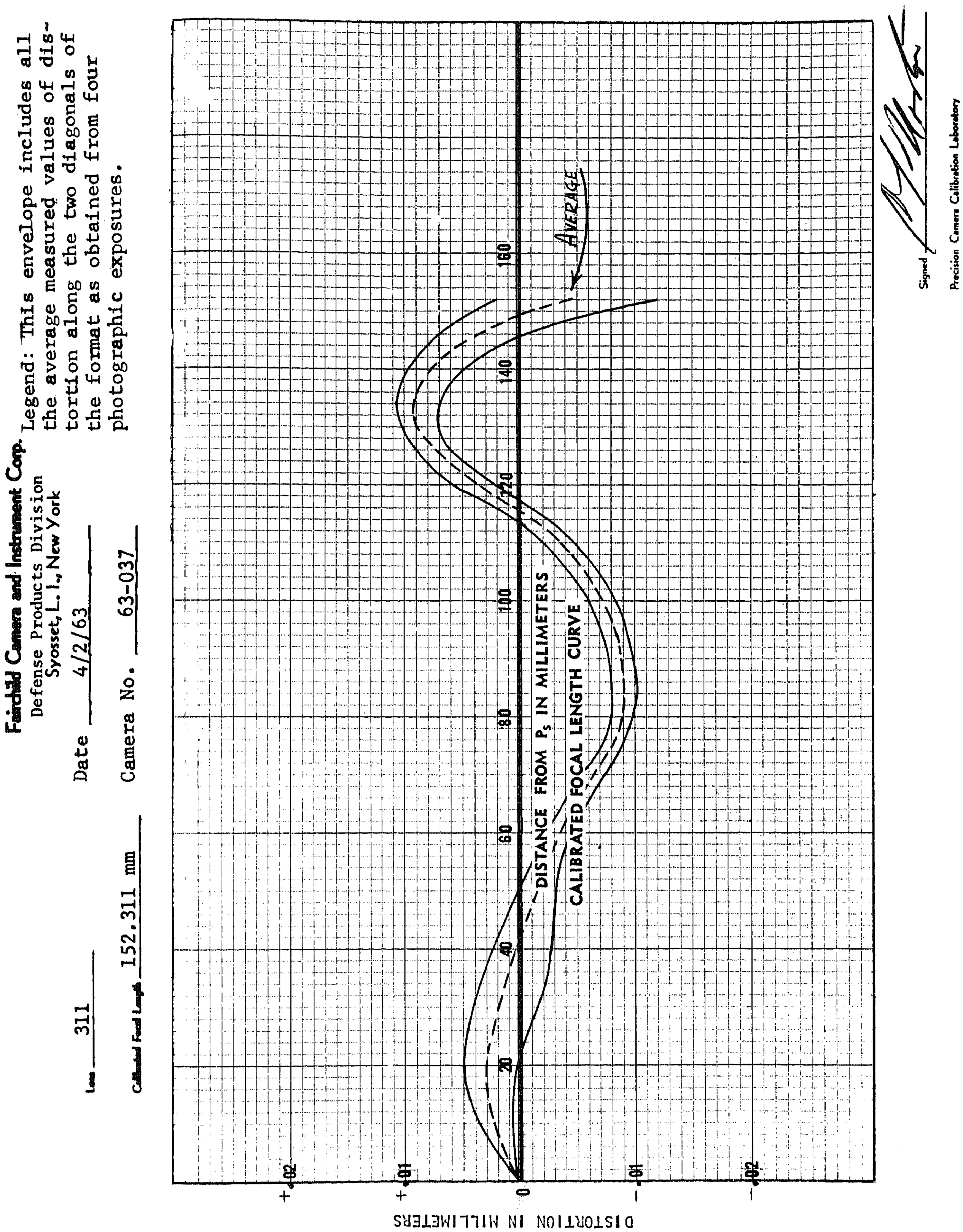


Figure E-2. Distortion characteristics.

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION
DEFENSE PRODUCTS DIVISION
SYOSSET, NEW YORK

CALIBRATION REPORT OF PLATEN FLATNESS

FCI 209

Part Number 691D2-1

Flantess vari. .00015

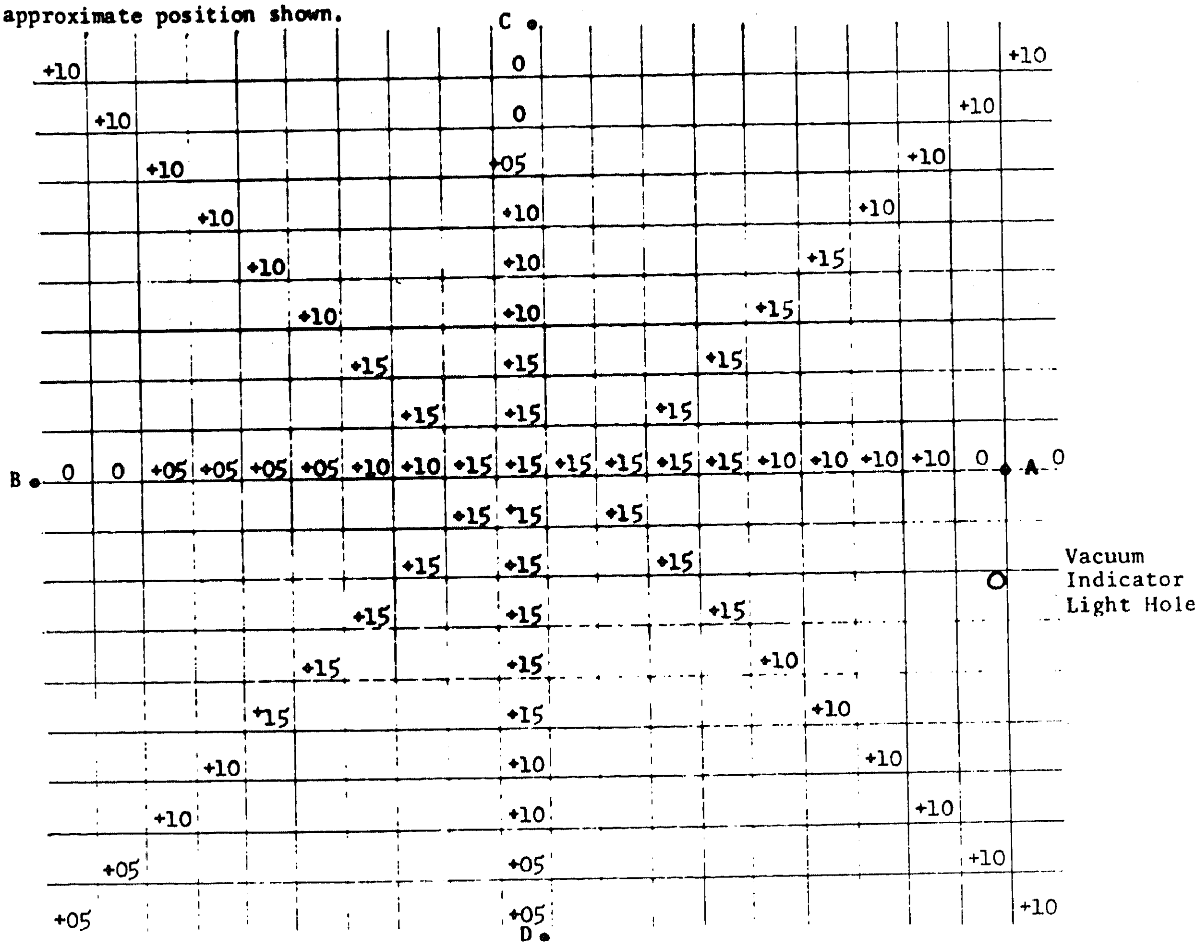
Order # 7302-49

Date 2/5/63

Platen No. 63-037

Flatness Variation Chart of Platen Flatness

Fiducial marks A - D - B - C shown on chart are referenced to Vacuum Indicator Light Hole in approximate position shown.



The numbers recorded on the chart are referenced to the grid of the platen and the camera fiducials. When the camera is pointed vertically downward, the negative values of deviation from a flat plane show the platen to be concave and represent an increase in focal distance for the reference area; positive values represent the reverse condition. Each number on the chart is multiplied by 10^{-5} inches as the number 10 appearing would represent 0.00010 inches.

The Platen Flatness is measured with a Sheffield Precision Air Gage Column and Air Spindle referenced to a Precision Ground Surface Plate. Precision of measurements obtained are 5×10^{-5} (0.000050 inches).

Chief Inspector

Figure E-3. Calibration report of platen flatness.

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Units org under fol TOE:
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5-306 (3)
5-307 (2)
5-308 (10)
5-327 (5)
5-346 (2)
5-347 (2)
5-348 (2)
5-349 (10)
5-540(IA-IL) (2)

NG: None.
USAR: None.
For explanation of abbreviations used see AR 310-50.

Air Force: F.

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